Space Div. N.

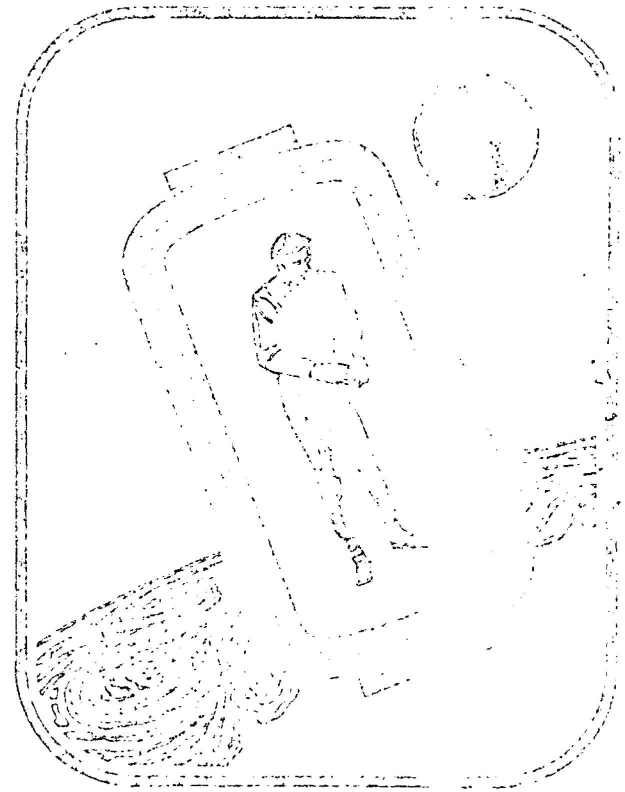
CR 115544

SD 71-532

MODULAR space station

PHASE B EXTENSION

NASA ADMINISTRATOR'S REVIEW



3 DECEMBER 1971

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(NASA-CR-115544) MODULAR SPACE STATION PHASE B EXTENSION NASA ADMINISTRATOR'S REVIEW (North American Rockwell Corp.) 3 Dec. 1971 144 p CSCL 22B

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Space Division
North American Rockwell

12214 Lakewood Boulevard
Downey, California

SD 71-582

MODULAR SPACE STATION

PHASE B EXTENSION

NASA ADMINISTRATOR'S REVIEW

December 3, 1971

Space Division
North American Rockwell

FOREWORD

This document has been prepared by the Space Division, North American Rockwell Corporation, in accordance with Exhibit C of contract NAS9-9953 statement of work for Phase B Extension - Modular Space Station Definition. The contents of this document were prepared for presentation to the Administrator of the National Aeronautics and Space Administration.

The documentation products of the Phase B extension study, prepared in accordance with the requirements of Data Requirements List (DRL) MSC-T-575, Line Item 68, are listed in the following chart in categories that indicate their purpose and relation to the program.

ADMINISTRATIVE REPORTS	TECHNICAL REPORTS		STUDY PROGRAMMATIC REPORTS	DOCUMENTATION FOR PHASES C AND D	
				SPECIFICATIONS	PLANNING DATA
EXTENSION PERIOD STUDY PLAN DRL-62 DRD MA-207T SD 71-211	MSS PRELIMINARY SYSTEM DESIGN DRL-68 DRD SE-371T SD 71-217	MSS DRAWINGS DRL-67 DRD SE-370T SD 71-216	EXTENSION PERIOD EXECUTIVE SUMMARY DRL-65 DRD MA-012 SD 71-214	MSS PRELIMINARY PERFORMANCE SPECIFICATIONS DRL-66 DRD SE-369T SD 71-215	MSS PROGRAM MASTER PLAN DRL-76 DRD MA-209T SD 71-225
QUARTERLY PROGRESS REPORTS DRL-64 DRD MA-208T SD 71-213, -235, -57[illegible]	MSS MASS PROPERTIES DRL-69 DRD SE-372T SD 71-218, -219	MSS MOCKUP REVIEW AND EVALUATION DRL-70 DRD SE-373T SD 71-220			MSS PROGRAM COST AND SCHEDULE ESTIMATES DRL-77 DRD MA-013(REV. A) SD 71-226
FINANCIAL MANAGEMENT REPORTS DRL-63 DRD MF-004	MSS INTEGRATED GROUND OPERATIONS DRL-73 DRD SE-376T SD 71-222	MSS KSC LAUNCH SITE SUPPORT DEFINITION DRL-61 DRD AL-005T SD 71-211			MSS PROGRAM OPERATIONS PLAN DRL-74 DRD SE-377T SD 71-223
	MSS SHUTTLE INTERFACE REQUIREMENTS DRL-71 DRD SE-374T SD 71-221	INFORMATION MANAGEMENT ADVANCED DEVELOPMENT DRL-72 DRD SE-375T SD 72-11			
	MSS SAFETY ANALYSIS DRL-75 DRD SA-032T SD 71-224				

CONTENTS

INTRODUCTION

STUDY APPROACH

MSS PRELIMINARY DESIGN

MSS REFERENCE PROGRAM

MSS PROGRAM COSTS

SORTIE & PROGRAM OPTIONS

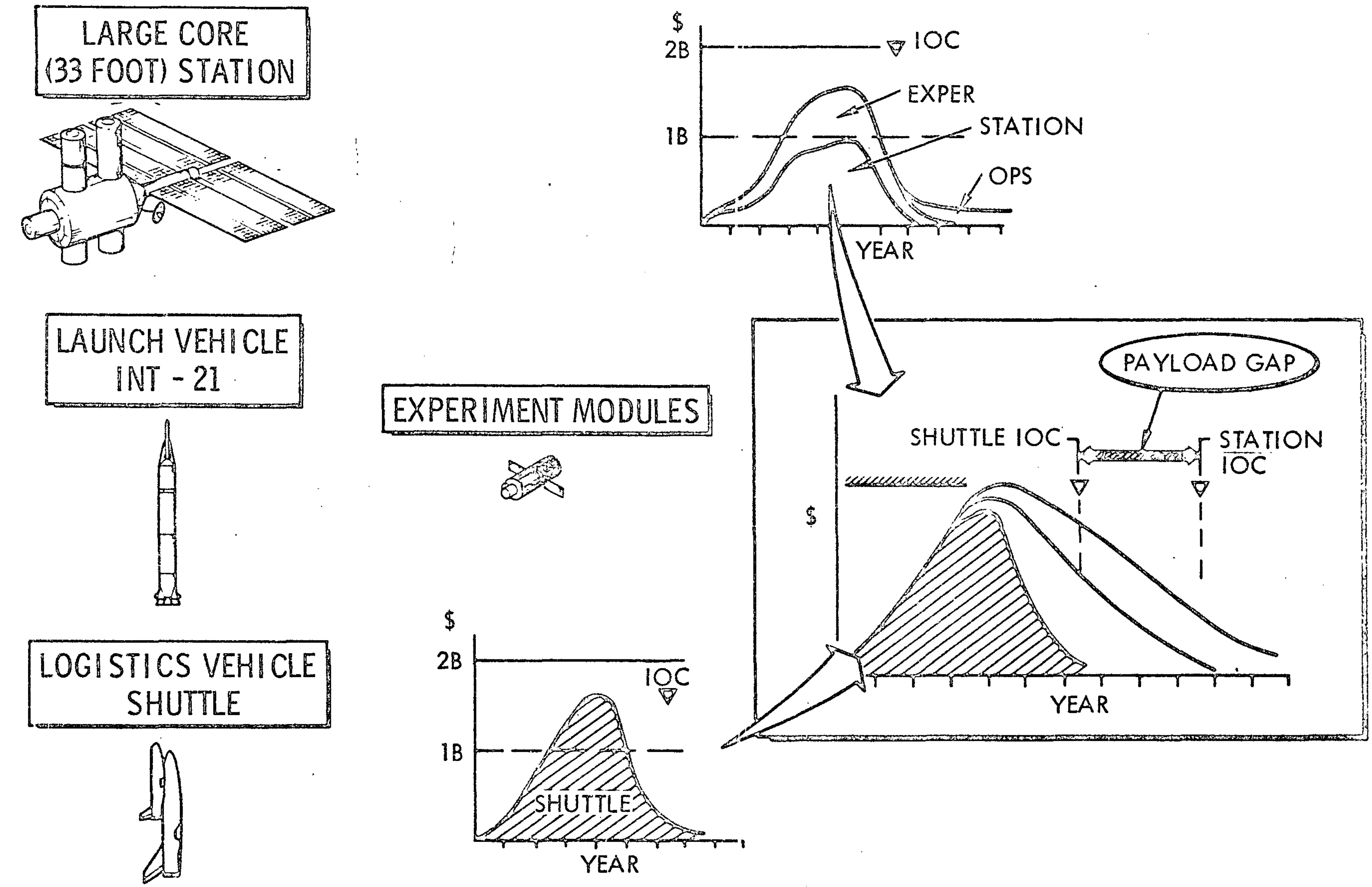
SYSTEM PROGRAMMATIC PROBLEM

The planning for an earth-orbital program has undergone, and is continuing to undergo, numerous revisions. A Phase B definition of a large-diameter space station system was completed by the fall of 1970. The solar-powered station was designed as a single self-contained facility for a crew of 12. Internal laboratory capability was provided, including airlocks, for general-purpose applications. Special-purpose experiment modules accommodated experiments operating either attached to the station or free flying.

The 33-foot diameter station system would be launched as a complete operable assembly on a single Saturn launch vehicle. Logistics support was provided by the space shuttle system.

Funding estimates for the two systems indicated very high annual requirements during the fourth and fifth years. It was apparent that concurrent operational dates for the station and shuttle would produce an unacceptable funding peak. The peak requirements could be reduced by deferring the station operation as well as by reducing the funding for both systems. The resulting difference in operational dates leaves a payload gap unless filled with systems with low funding requirements.

SYSTEM PROGRAMMATIC PROBLEM - FALL OF 1970



POTENTIAL TECHNICAL SOLUTION TO SYSTEM PROBLEM

The solar-powered, 33-foot diameter space station contained crew and habitability provisions designed for supporting a crew for extended periods. General-purpose laboratory provisions were also contained on selected decks with capability to carry out experiments not assigned to attached or detached modules.

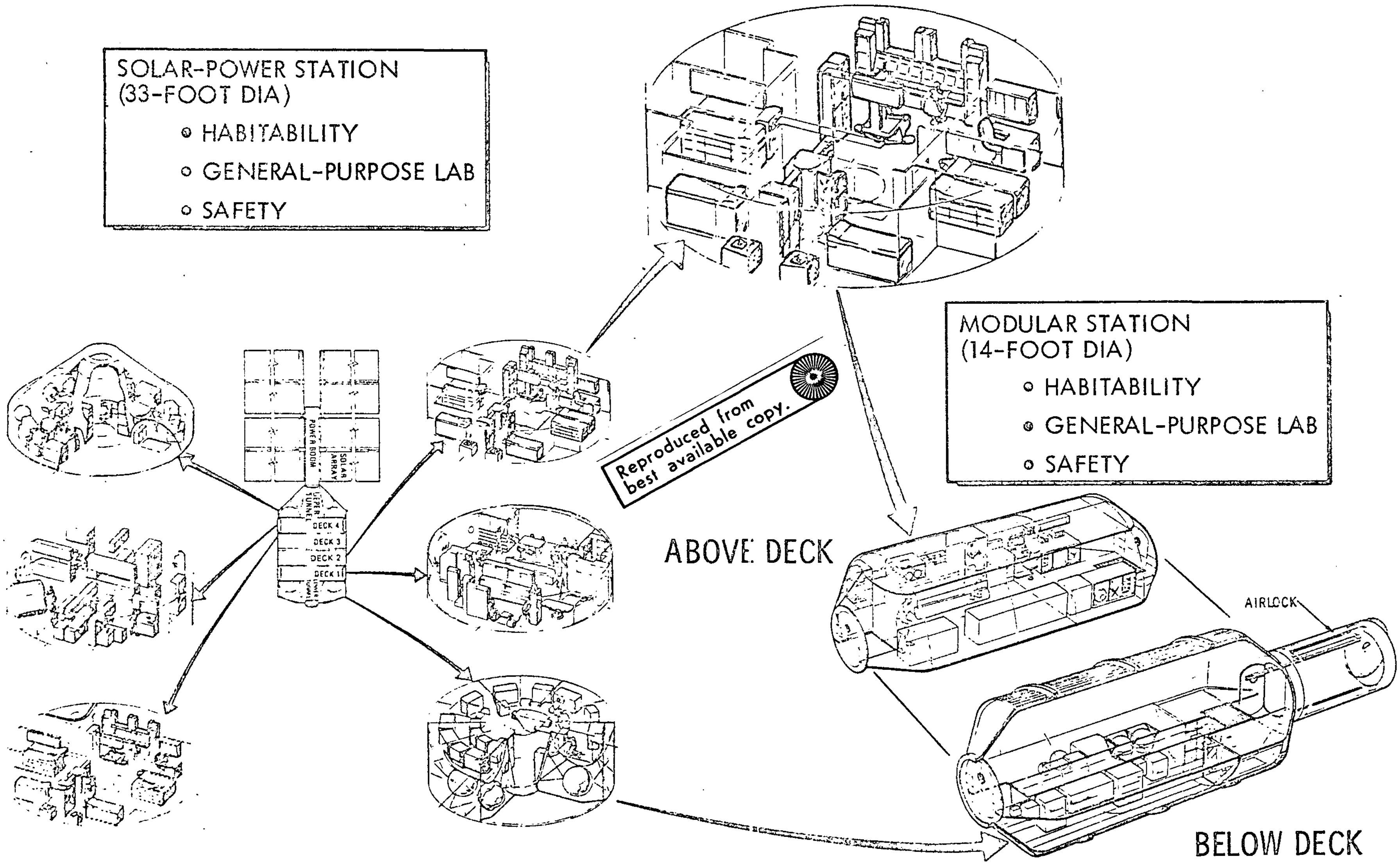
Dual, pressure-isolatable volumes provided the crew with safe continued operation in either volume when the utility of the other volume is impaired. Subsystem assemblies and tanks were installed in a maintainable arrangement in the sections at the end of each habitable volume.

The same safety and habitability criteria can be applied to the design of the modular space station. In arranging facilities and grouping equipment into the 14-foot diameter modules, approximately one-half of the full-height facilities of a 33-foot diameter deck occupied the upper deck of the smaller module. Subsystem assemblies, below deck, in the 14-foot diameter module were approximately equal to one-half of the 33-foot diameter installation. Thus, six of the 14-foot modules are required for equal accommodations.

POTENTIAL TECHNICAL SOLUTION TO SYSTEM PROBLEM

SOLAR-POWER STATION
(33-FOOT DIA)
- HABITABILITY
- GENERAL-PURPOSE LAB
- SAFETY

MODULAR STATION
(14-FOOT DIA)
- HABITABILITY
- GENERAL-PURPOSE LAB
- SAFETY

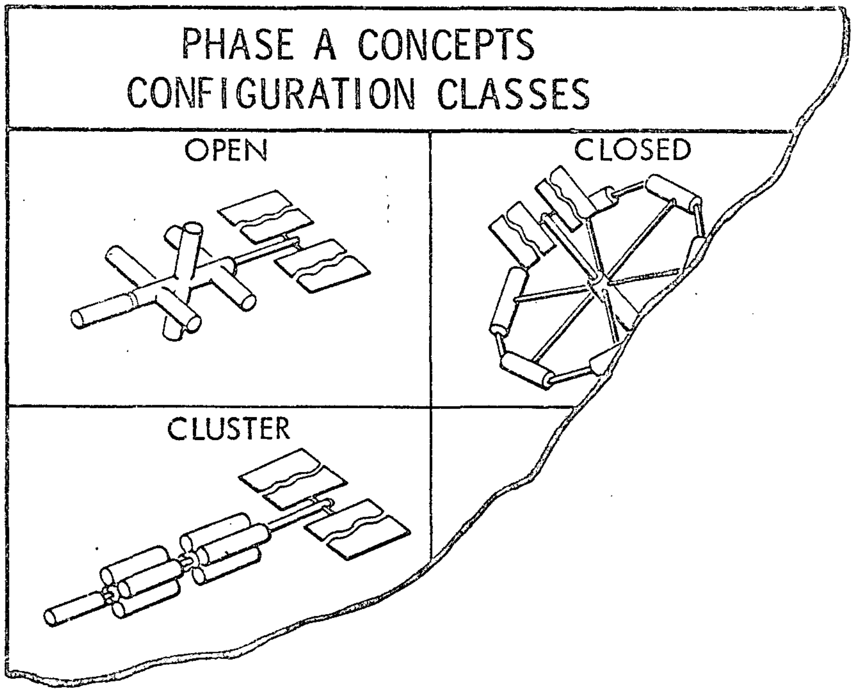


MSS PHASE B STARTING POINT

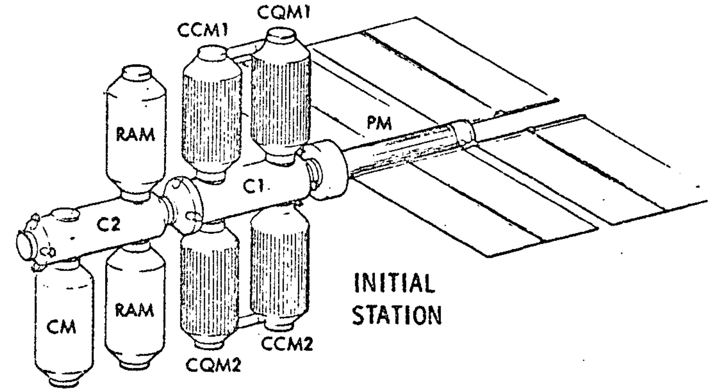
The Phase A study of the modular space station investigated 13 configurations of four types or classes. The open class, characterized by a central module or core with crew and facility modules end-docked, was recommended for further definition. The cruciform and barbell configurations are alternatives of the open class. In both configurations the station module containing crew, control, and laboratory facilities are docked in the same plane. The barbell configuration has RAM's and cargo module docked in the same plane, but in the cruciform they are docked in the plane normal to the station modules. The study showed that the same station modules could be applied to either configuration with increased core module length in the barbell. The Phase B study was initiated with a barbell configuration baseline with an added consideration of a manipulator which was not part of the Phase A analysis.

The Phase B study program baseline included two steps or capability plateaus, initially a 6-man station capability followed after five years of operation by growth to a 12-man station. The growth station was to be capable of carrying out all the experiment laboratories of the NASA 1971 Blue Book.

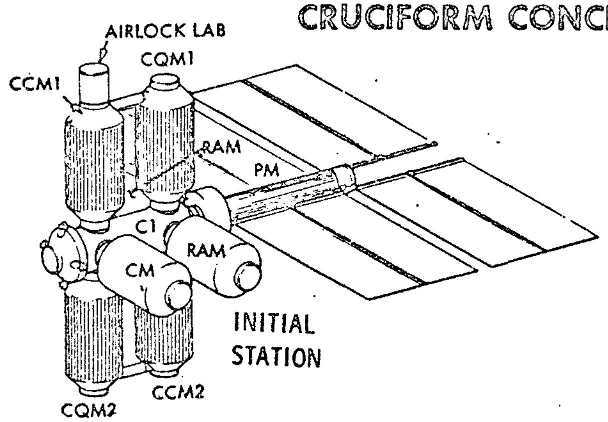
MSS PHASE B STARTING POINT



BARBELL CONCEPT



CRUCIFORM CONCEPT



PHASE B START BASELINES

- BARBELL, MANIPULATOR
- TWO-STEP (6, 12) PROGRAM BUILDUP

EXPERIMENT ACCOMMODATION MODES

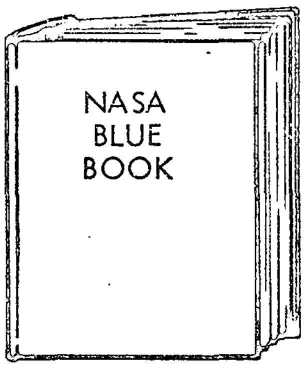
The 1971 Blue Book described the types of facilities, experiment operations, and the equipment capable of accomplishing the stated objectives for seven disciplines. Twenty-five equipment groups are required to conduct the 230 experiments.

The operation of some of these groups requires accommodation in free-flying modules to achieve the experiment objectives. Other groups can be accommodated either integral or attached to a manned spacecraft.

Partial groups of experiment and support equipment can also be selected to carry out selected experiment objectives of each of the seven disciplines.

The full or partial equipment groups can be accommodated with the modular station operated in integral general-purpose laboratories or in attached modules. Partial equipment groups can be accommodated in the short duration sortie mode, attached to the space shuttle.

EXPERIMENT ACCOMMODATION MODES



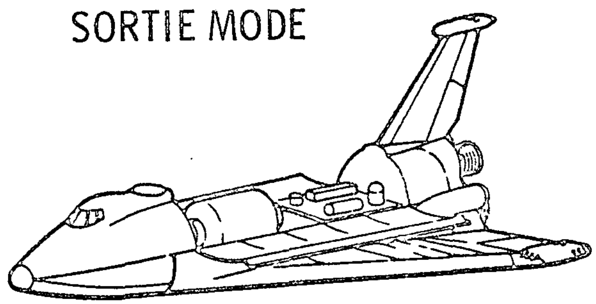
7 DISCIPLINES

- ASTRONOMY
- PHYSICS
- EARTH OBSERVATIONS
- COMM/NAV
- MATERIAL SCIENCES
- TECHNOLOGY
- LIFE SCIENCES

230 EXPERIMENT OPERATIONS

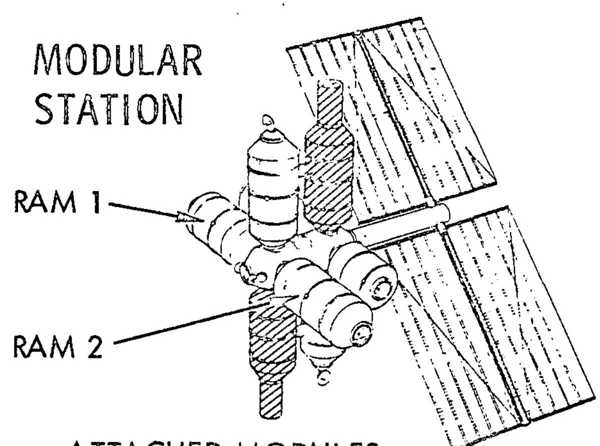
25 EQUIPMENT GROUPS

SORTIE MODE



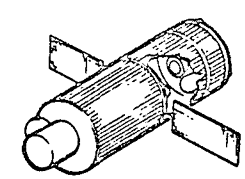
- ATTACHED

MODULAR STATION



- ATTACHED MODULES
- INTEGRAL LABS

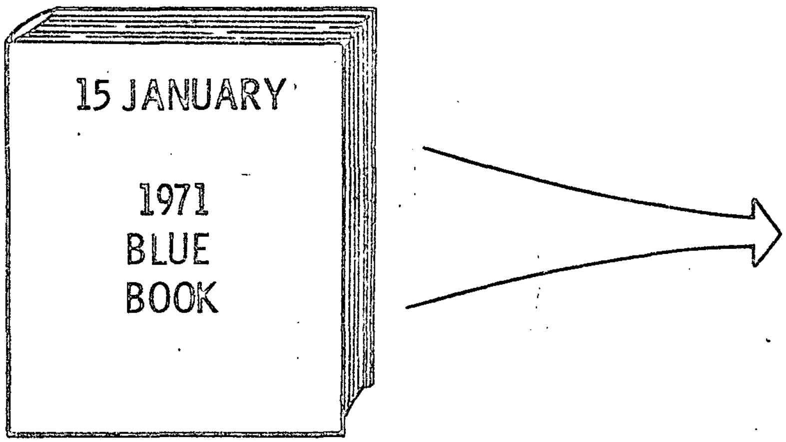
FREE-FLYING MODULES



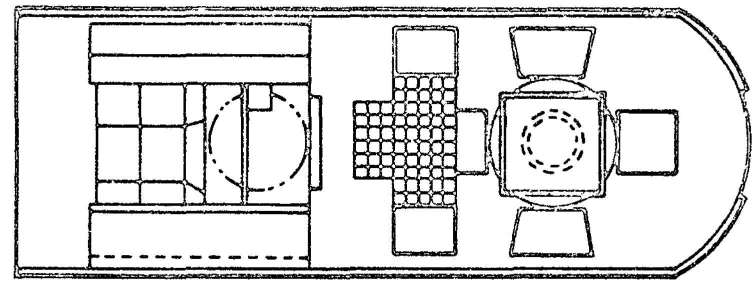
LABORATORY EVOLUTION PHILOSOPHY

One major feature of the 1971 Blue Book is the introduction of the laboratory concept. A set of laboratories is described which contains experiment equipment capable of accomplishing a wide variety of earth-orbital science and applications objectives. NR has defined a series of buildup steps for each of these Blue Book-defined laboratories. This evolution of capability is a major feature of NR's overall programmatic approach consistent with an evolution of carrier vehicle capability.

LABORATORY EVOLUTION PHILOSOPHY



"FACILITY CONCEPT"

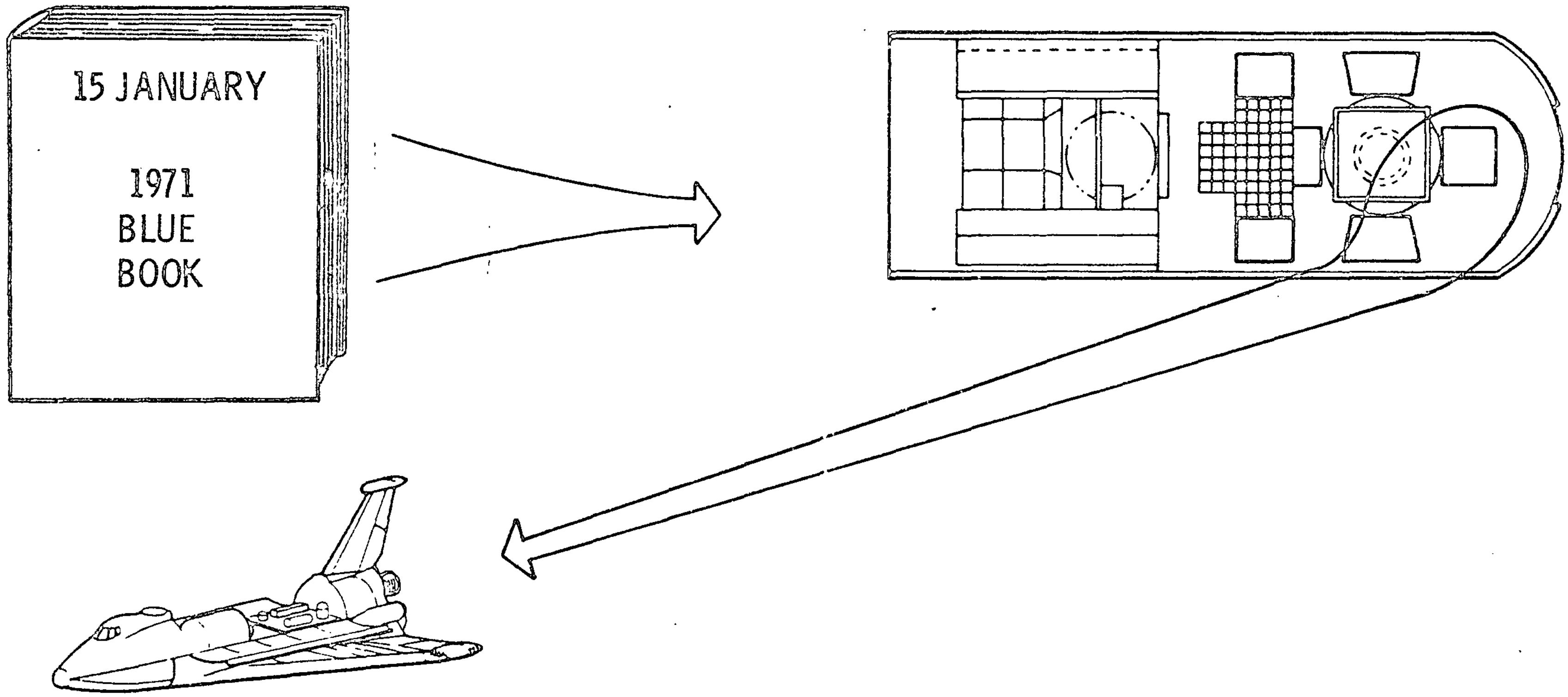


LABORATORY EVOLUTION PHILOSOPHY - LEVEL I

The initial step in the evolution establishes experiment packages that are fundamental portions of an eventual facility and that are (1) compatible with the sortie mission mode and (2) provide early low-cost benefits and applications. These packages (subsequently consolidated with other packages into combined payloads) were essentially precursors to the initial level of experiments on the space station.

LABORATORY EVOLUTION PHILOSOPHY

"FACILITY CONCEPT"



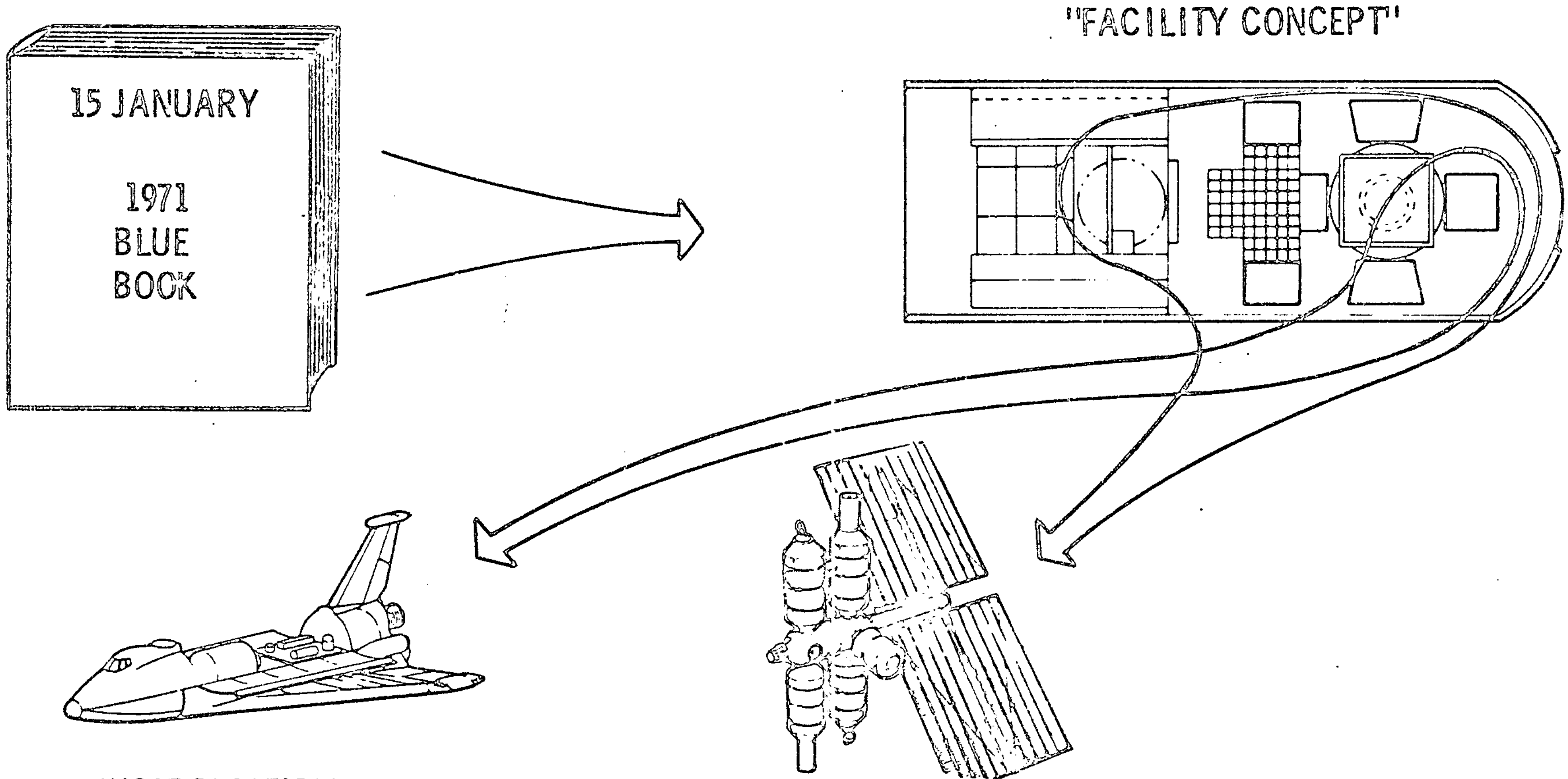
- SHORT DURATION
- EARLY BENEFIT
- IMMEDIATE APPLICATION
- LEVEL II PRECURSORS

**LEVEL 1
EXPERIMENT PACKAGES**

LABORATORY EVOLUTION PHILOSOPHY - LEVEL II

Level II adds equipment associated with long duration or permanent-type experiments emphasizing a balanced but low-cost program. In general, high-cost research and scientific-oriented equipment is deferred to the final level.

LABORATORY EVOLUTION PHILOSOPHY



- SHORT DURATION
- EARLY BENEFIT
- IMMEDIATE APPLICATION
- LEVEL II PRECURSORS

LEVEL 1
EXPERIMENT PACKAGES

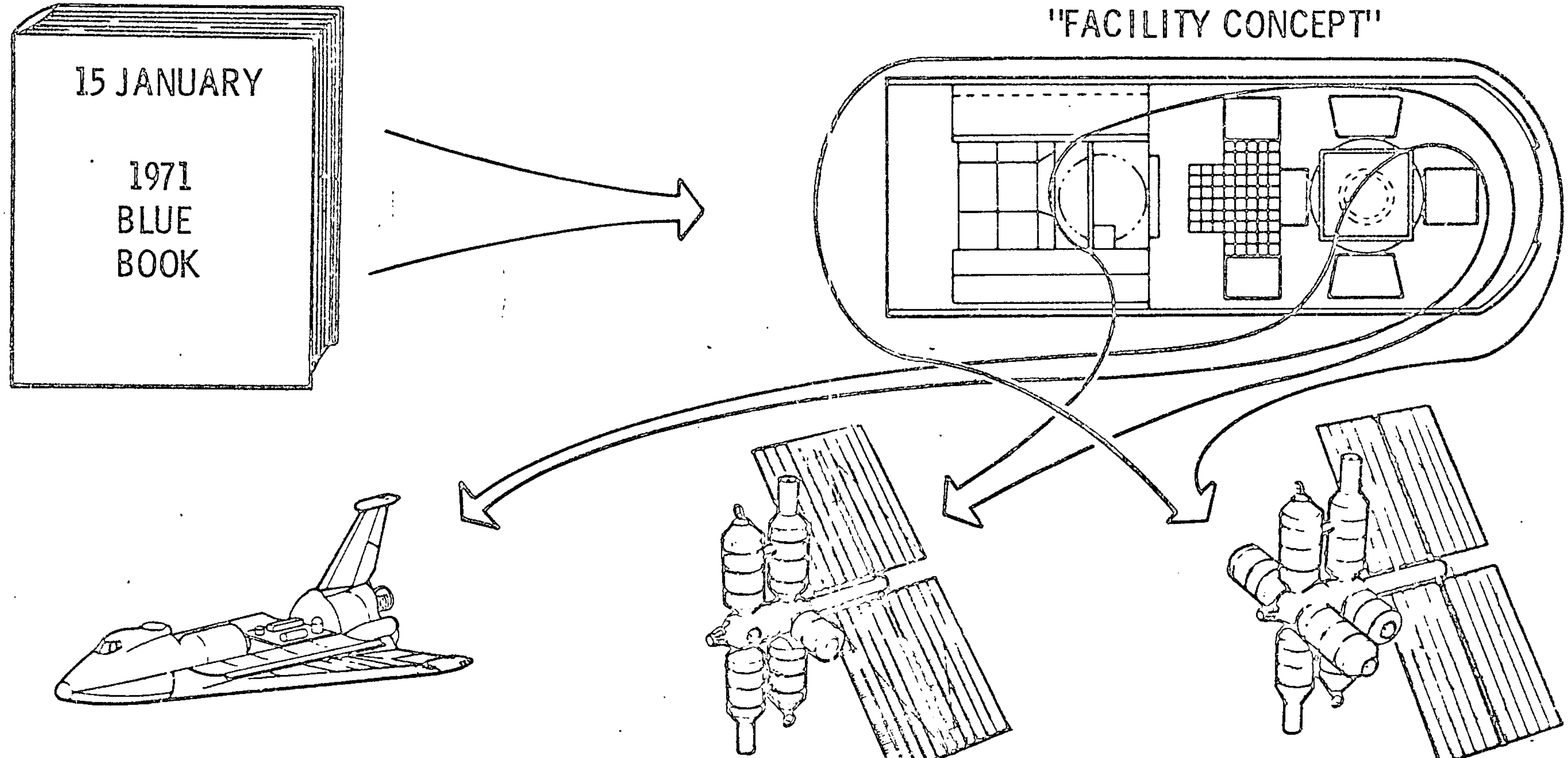
- CONTINUE HIGH BENEFITS
- BALANCED LOW COST PROGRAM
- LEVEL III PRECURSORS

LEVEL II
PARTIAL LABORATORIES

LABORATORY EVOLUTION PHILOSOPHY - LEVEL III

Level III consists of the total Blue Book facility

LABORATORY EVOLUTION PHILOSOPHY



- SHORT DURATION
- EARLY BENEFIT
- IMMEDIATE APPLICATION
- LEVEL II PRECURSORS

LEVEL I
EXPERIMENT PACKAGES

- CONTINUE HIGH BENEFITS
- BALANCED LOW COST PROGRAM
- LEVEL III PRECURSORS

LEVEL II
PARTIAL LABORATORIES

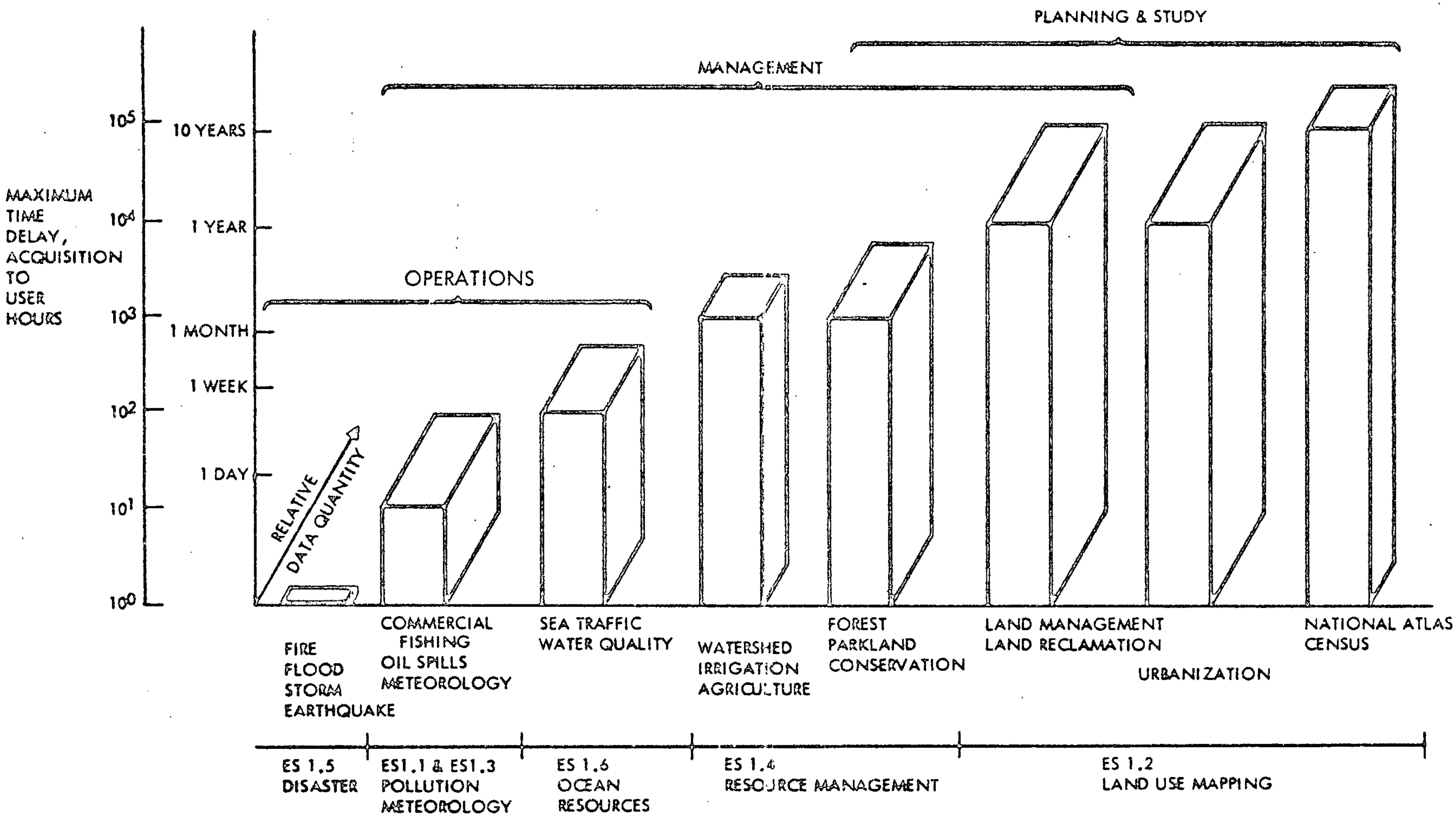
- FULL BLUE BOOK CAPABILITY

LEVEL III
COMPLETE
LABORATORIES

EARTH OBSERVATIONS DATA USER REQUIREMENTS

Key factors in developing the evolution philosophy for the earth observations laboratory are the quantity of data to be acquired and the rapidity with which they must be disseminated to the users. Plotted here, for a wide range of areas of interest, is the relative maximum permissible "aging" of various types of data and their relative quantities. Corresponding Blue Book earth observations experiments are indicated at the bottom of the chart. Inherently, systems that must disseminate data from sensor to user in near real time are significantly more complex and sophisticated than systems in which time delays in terms of months or years are permissible. Therefore, the experiments selected for Level I should be those typical of the right-hand side of the chart, and those deferred to Level II and III should be those typical of the left-hand side of the chart.

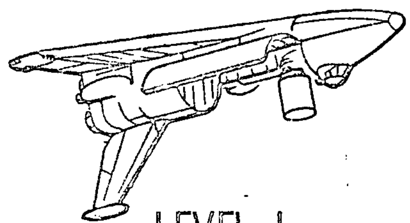
EARTH OBSERVATIONS DATA USER REQUIREMENTS



EARTH OBSERVATIONS LABORATORY EVOLUTION

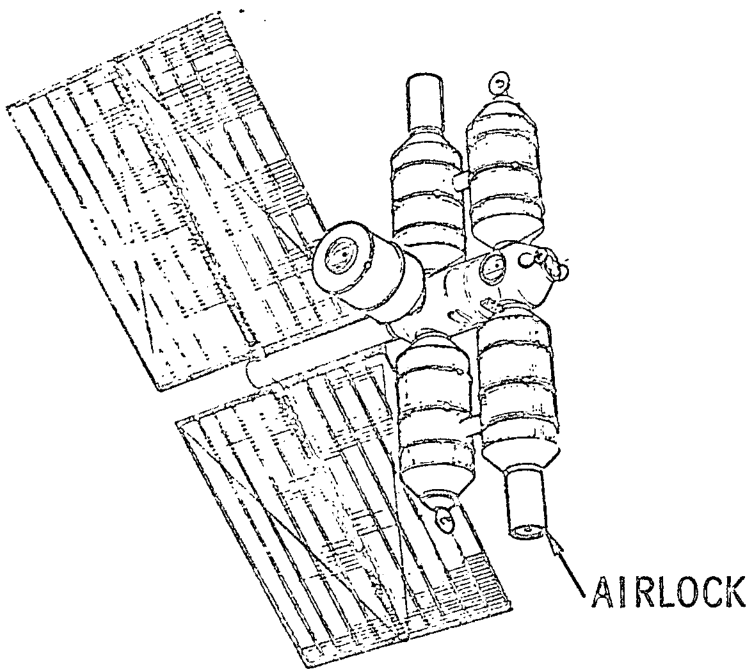
The experiments selected for earth observations Level I are those associated with slowly changing phenomena, such as land use mapping and geology. Also selected are precursor experiments such as signature research and simplified remote sensing techniques. At Level II more sophisticated, shorter turnaround experiments are introduced such as pollution monitoring. The sensors can be deployed in groups sequentially through an air-lock, thereby deferring the need for a dedicated RAM. At Level III an all-up earth observations facility capable of deploying all sensors simultaneously will be employed.

EARTH OBSERVATIONS LABORATORY EVOLUTION



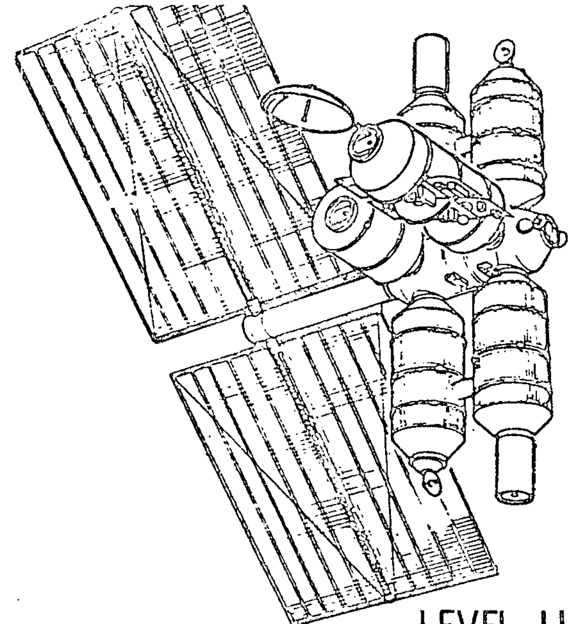
LEVEL I

- SENSOR DEVELOPMENT
- SLOWLY CHANGING PHENOMENON



LEVEL II

- AIRLOCK DEPLOYMENT
- SENSOR GROUPS EVALUATED
- RESOURCE MGMT, POLLUTION MONITORING



LEVEL III

- FULL CAPABILITY
- INTEGRATED SENSOR GROUPS
- REAL TIME DATA DISSEMINATION

EXPERIMENT LEVEL SUMMARY

The experiment related items necessary to accomplish the NASA-defined 1971 Blue Book are summarized on this chart. The summary is presented in terms of the number of experiments, major equipment items, and experiment equipment groups for each level of activity. The requirements defined for Level III are dictated by the 25 experiment equipment groups in the Blue Book. Within these 25 experiment equipment groups, there are 230 experiments which require 744 major experiment equipment items.

The experiment equipment group accommodation modes also are presented. At Level II, 15 of the experiment equipment groups are accommodated in the space station while 11 are accommodated in the station at Level III. The attached experiment equipment groups are accommodated in attached research and applications modules (RAM's) and the free-flyer groups are accommodated in detached RAM's. To accomplish the reference experiment program, a total of 6 attached RAM's and 7 detached RAM's are required. This number includes consideration of reconfiguring RAM's between Level II and Level III.

EXPERIMENT LEVEL SUMMARY

	LEVEL I	LEVEL II	LEVEL III
NO. OF EXPERIMENTS	63	146	230
MAJOR EQUIPMENT ITEMS	378	482	744
EXPERIMENT EQUIPMENT GROUPS	32	26	25
EQUIPMENT GROUP ACCOMMODATION MODES			
SHUTTLE ATTACHED	32		
STATION INTEGRAL		15	11
STATION ATTACHED		9	7
FREE FLYER		2	7

EXPERIMENT PROGRAM SENSITIVITY

A paradox in the Space Station Program is that subsystem concepts have to be selected and design requirements established far in advance of final experiment program selection. It is therefore important to determine whether a "point-design" space station will place limitations on the type of experiment program it will support.

To answer this question, NR attacked the issue in reverse by conducting a sensitivity analysis to determine the impact on station design and subsystems of major changes in experiment program emphasis. This was done by identifying three distinctly different experiment program types, evolving the phased resources required to support each, and analyzing the impact on the station of each set of resource requirements. The three program types were:

Program A - emphasis on early socio-economic benefits

Program B - empahsis on high priority science

Program C - a balance of emphasis of benefits and science

The analysis showed that there was no significant difference in station design and subsystem requirements among the three programs. Based on this, NR has concluded that final space station sizing and design will be relatively insensitive to changes in experiment program emphasis and, conversely, a space station so designed will have the flexibility to accommodate any desired experiment program.

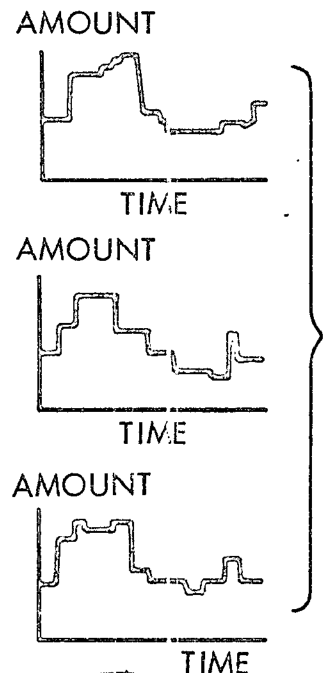
EXPERIMENT PROGRAM SENSITIVITY

KEY ISSUE: DOES STATION DESIGN DICTATE TYPE OF EXPERIMENT PROGRAM?

PROGRAM EMPHASIS

- TYPE A EARLY SOCIO-ECONOMIC BENEFITS
  - EARTH OBSERVATIONS
  - BIOMEDICAL RESEARCH
  - MATERIALS SCIENCE
- TYPE B EARLY HIGH PRIORITY SCIENCE
  - SOLAR, STELLAR ASTRON
  - ANIMAL & PLANT BIOLOGY
  - X-RAY ASTRONOMY
- TYPE C BALANCED EMPHASIS
  - EARTH OBSERVATIONS
  - BIOMEDICAL RESEARCH
  - SOLAR ASTRONOMY

REQUIREMENTS

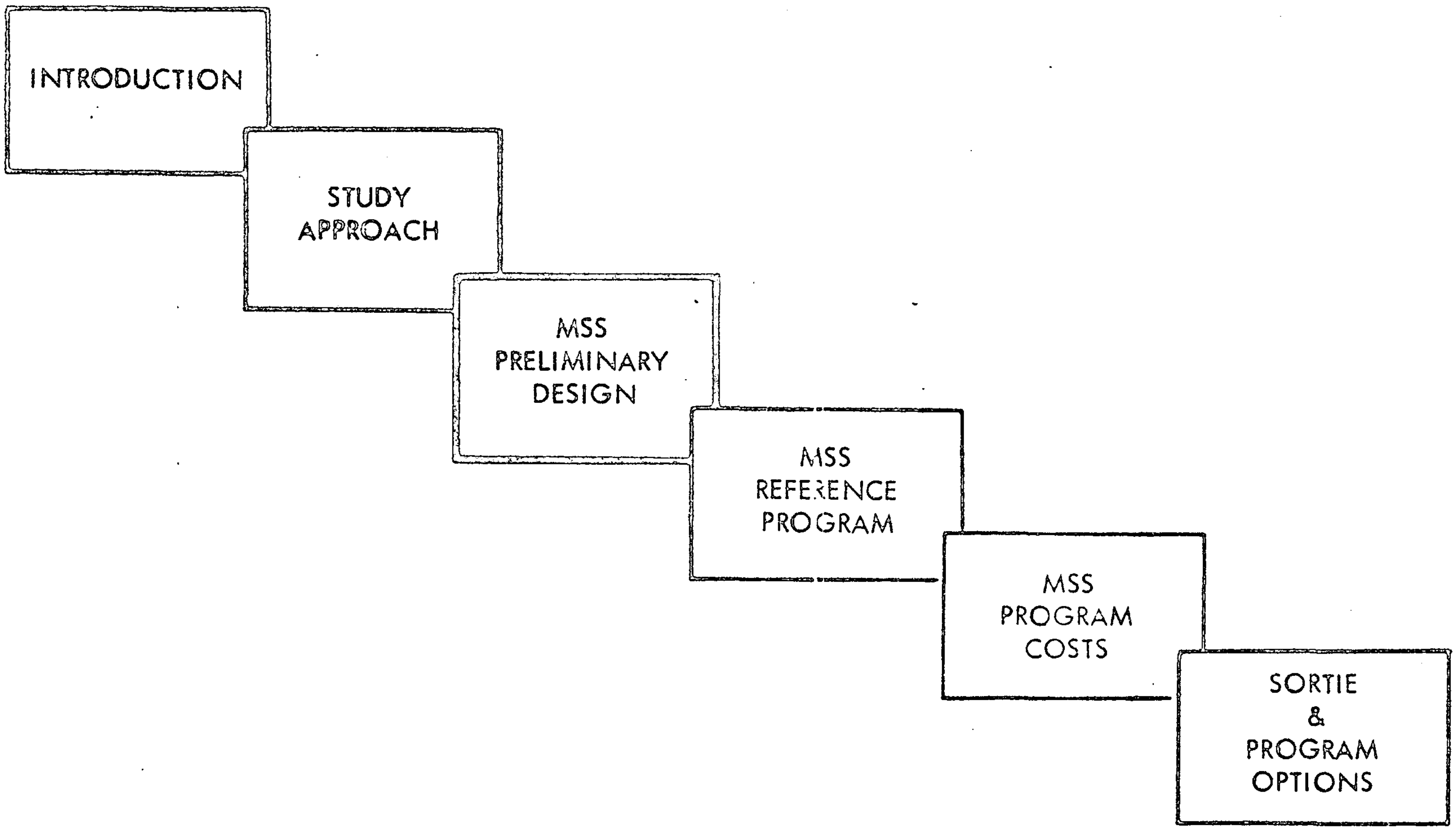


NO SIGNIFICANT DIFFERENCES

- POWER
- LOGISTICS
- DATA
- STABILITY
- CONTAMINATION
- CREW MAN-HOURS

CONCLUSION

STATION DESIGN & SUBSYSTEMS RELATIVELY INSENSITIVE TO EXPERIMENT PROGRAM TYPE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SORTIE & PROGRAM OPTIONS

INITIAL STATION BUILDUP APPROACH

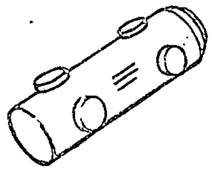
The initial module to be delivered to orbit preferably has a minimum amount of scar equipment above that required for normal operations. In the second quarterly review, it was shown that this objective was best achieved with the core module launched first. This is followed by the power module. These two assembled modules are flown in a gravity-gradient mode at minimum (nearly quiescent) power between buildup launches.

A subsequent launch adds the crew/control module. The solar arrays are partially deployed and operated automatically with the now present ISS. The configuration is now flown oriented about the principal axis, and the regenerative segments of the fuel cells are activated. In subsequent sequence, the first lab/ECLSS module, the second lab/ECLSS module, and the second crew/control module are added at 30-day launch intervals.

Although this chart indicates the sequence of buildup, there are still station module alternative sequences that are visible options. An example would be SM-3 before SM-2. This provides a more balanced configuration, but defers the early flexport assembly between SM-1 and SM-2.

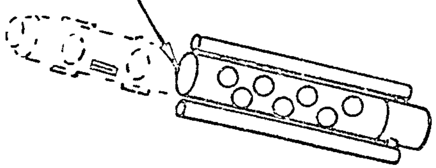
INITIAL STATION BUILDUP APPROACH

① CORE
- GRAVITY GRADIENT MODE
- ACTIVE THERMAL CONTROL
- WAKE-UP G&C/RCS
- FUEL CELL POWER

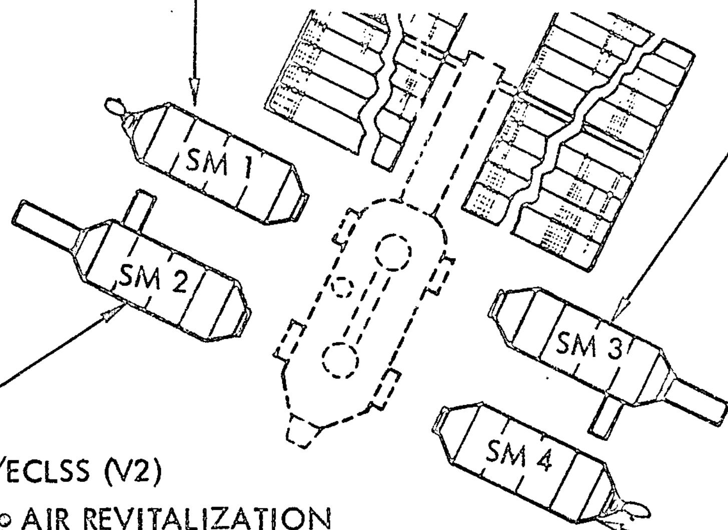


③ CREW/CONTROL (V1)
- DEPLOY ARRAY
- ACTIVATE THERMAL CONTROL
- CLOSED-LOOP EPS
- ANTENNA PACKAGE

② POWER
- RETRACTED ARRAYS
- 2ND 30 DAY EPS O_2/H_2



⑤ LAB/ECLSS (V1)
- AIR REVITALIZATION
- AIRLOCK (CELESTIAL)



④ LAB/ECLSS (V2)
- AIR REVITALIZATION
- AIRLOCK (NADIR)

⑥ CREW/CONTROL (V2)
- REDUNDANT CONTROL
- ANTENNA PACKAGE

INITIAL STATION BUILDUP APPROACH (CONT)

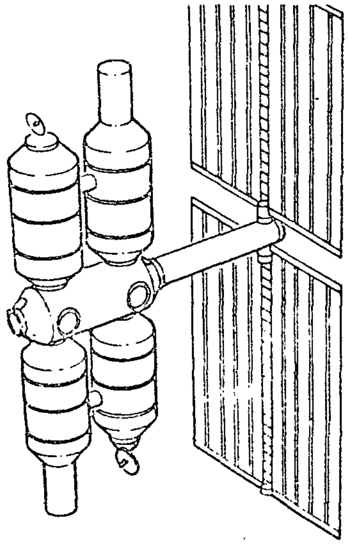
With the addition of a cargo module and the six-man crew, the configuration has reached its initial operational capability (IOC).

In addition to the configuration arrangement results shown, two isolatable pressure volumes and dual ingress-egress paths from all station modules (with flexports) and core module are provided. Completely redundant systems provide crew safety and a continuous operation capability which maximizes crew utilization time on orbit. Station module spacing (5 feet between modules) has been selected to permit direct docking on modules as an alternative to berthing modules with the manipulator. Also, the initial station configuration arrangement allows the best access for later buildup to the growth configuration.

INITIAL STATION BUILDUP APPROACH (CONT)

7 CARGO MODULE

- 96 HR EMERGENCY SUPPLIES
- CREW & CREW PERSONAL ITEMS
- CONSUMABLES & SPARES



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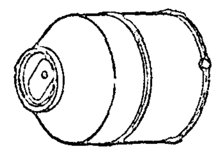

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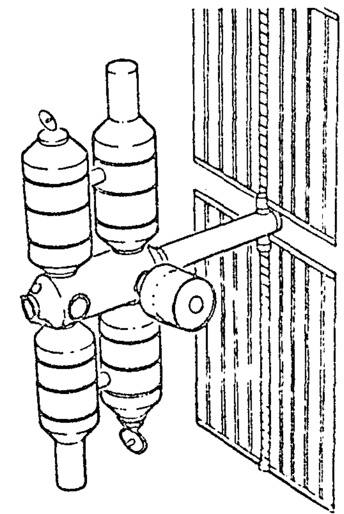
IOC



ALLOWS

- SIMPLE LIGHTWEIGHT POWER BOOM
- MINIMUM SUBSYSTEM SCAR
- EARLY MANNED CAPABILITY

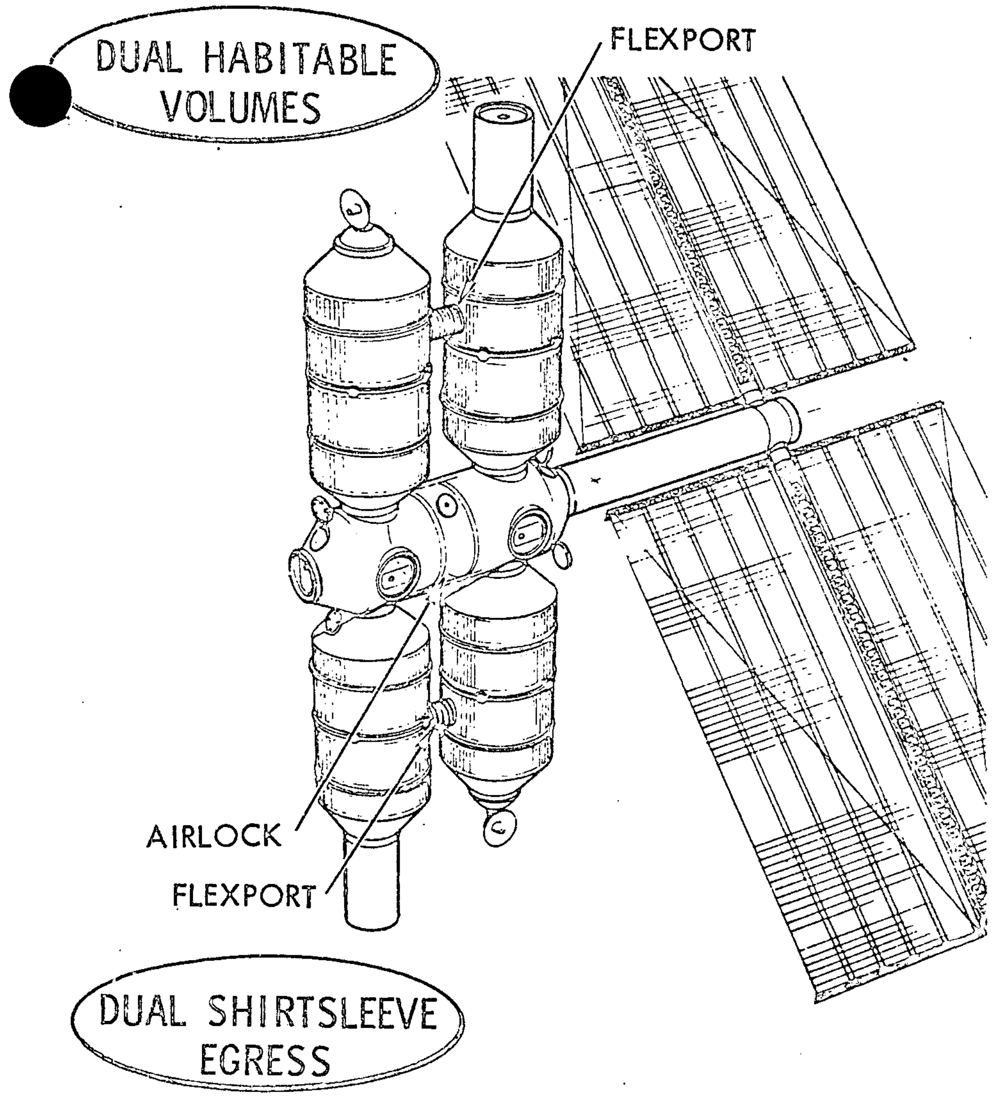
MSS CONFIGURATION DESIGN FEATURES - SAFETY

Application of safety criteria during the trades and preliminary design resulted in a station configuration with dual habitable volumes connected through station modules by means of flexports to adjacent modules to provide alternate shirtsleeve passageways. The combination of flexport and single station module also provides backup airlock capability for IVA between volumes as well as EVA in the case where the normal EVA-IVA airlock is inoperable.

Subsystem redundancy and installation in the two pressure volumes provides habitability, life support, and station control with any module or volume lost due to depressurization, fire, or presence of hazardous atmosphere.

Additional safety criteria were developed during the study and implemented in the preliminary design. Significant criteria include safety factors of 4.0 for pressure vessels located in inhabited areas, particularly when used as accumulators, and a requirement that all hazardous fluid containers, lines, and components be double-contained with provision for venting the intermediate volume to space. The failure tolerance criteria were clarified and related to critical functions on a station-wide basis, both during manned operations and the unmanned buildup period when criticality relates to successful docking with the portion of the station in orbit.

MSS CONFIGURATION DESIGN FEATURES - SAFETY



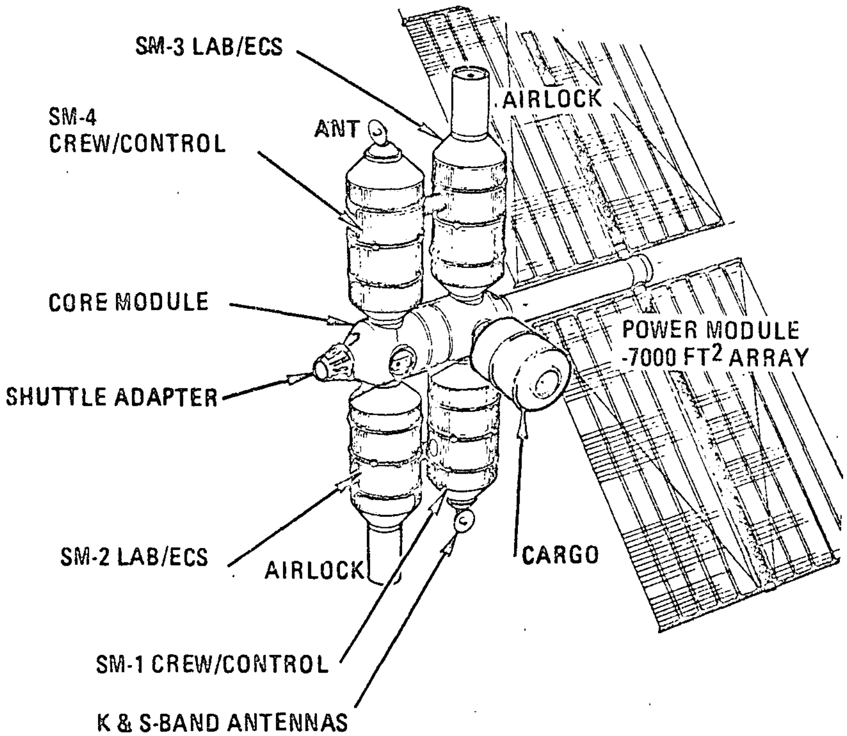
- CAPABLE OF MISSION CONTINUATION IN EITHER VOLUME
  - 1/2 VOLUME HABITABLE FOR EXTENDED PERIOD WHEN UTILITY OF OTHER VOLUME IS IMPAIRED
- SUBSYSTEM REDUNDANCY DIVIDED BETWEEN VOLUMES
  - DUAL VOLUME ACHIEVED WITHOUT ADDED EQUIPMENT
  - ACCOMMODATES MODULE REPLACEMENT
- DUAL SHIRTSLEEVE EGRESS
  - FROM EACH PRESSURIZED MODULE
  - BETWEEN DUAL VOLUMES
- DUAL EVA/IVA BETWEEN VOLUMES

PRELIMINARY DESIGN CONFIGURATION INITIAL STATION

The modular space station configuration is arranged for an initial operational capability at a crew size of six, with provisions for addition of modules to operate with a crew size of 12. The initial station configuration consists of four common station modules, power and core modules, and a cargo module. The station modules are assembled on the core module in a single plane (Z axis) which is normally vertical to the earth's surface. Spacing between modules can accommodate either manipulator berthing or direct docking assembly modes. The two laboratory modules have experiment airlocks attached at the outer ports; one provides zenith or celestial pointing for experiments, the other earth pointing along the local vertical. The two crew/control modules have removable packages attached that contain K, S, and VHF band antennas. The power module is designed for solar array replacement by removing the turret and arrays from the module.

The cargo modules are docked in the Y plane, on one side of the core and then the other on successive cargo deliveries. Cargo modules normally use the core module ports nearest the power module. The other ports are available for operation or service of RAM's. The operational configuration varies as RAM's are added or returned to earth.

PRELIMINARY DESIGN CONFIGURATION
INITIAL STATION

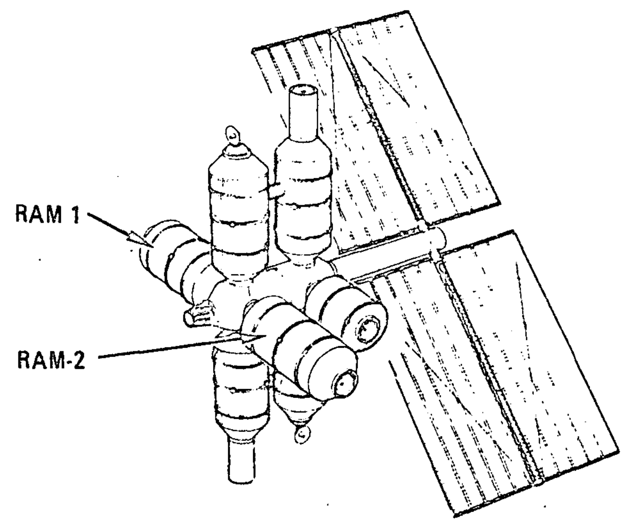


VOLUME ALLOCATION

○ EXPERIMENT ACTIVITY	7649 FT^3
○ CREW/SUBSYSTEMS	10,648 FT^3
○ COMMON USAGE	6363 FT^3

- MODULES
  - FOUR COMMON STATION MODULES
  - TWO SPECIAL MODULES
  - ONE CARGO MODULE
- ASSEMBLY/REPLACEMENT
  - MANIPULATOR BERTHING OR DIRECT DOCKING
  - ON-ORBIT REPLACEMENT ANTENNA PACKAGES, EXPERIMENT AIRLOCKS & SOLAR ARRAY

OPERATIONAL CONFIGURATION WITH TWO ATTACHED RAMS



INTEGRATED SUBSYSTEMS (EPS, ECLSS, RCS)

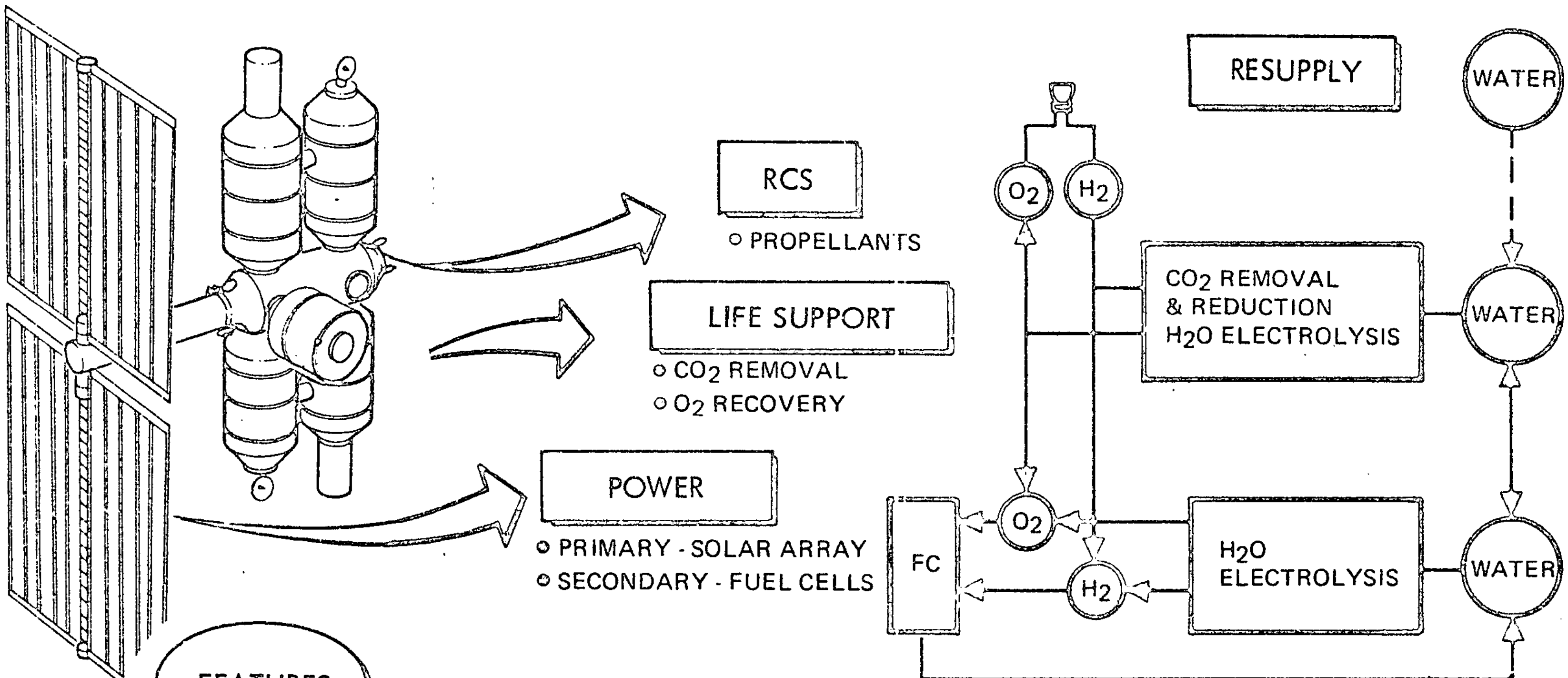
The EPS will utilize four regenerative fuel cell assemblies, each consisting of one fuel cell, electrolysis unit, H_2 accumulator, O_2 accumulator, and half of a water storage tank. The assembly can receive or supply in an emergency H_2, O_2, or water to the ECLSS and RCS.

The ECLSS uses a closed O_2 and water cycle concept consisting of H_2 depolarizer for CO_2 removal, Sabatier for CO_2 reduction, electrolysis for O_2 recovery and for RCS H_2/O_2 generation, and vapor compression for water reclamation.

The RCS stores H_2/O_2 gases generated at 300 psia by the ECLSS.

The design integrates the gas generation and gas/water storage functions for all subsystems and maximizes the use of common hardware. The EPS and ECLSS use similar electrolysis units compatible with SSP technology. The EPS energy storage and secondary (emergency) power are supplied by shuttle-developed fuel cells. All subsystems use electrochemical processes based on the H_2 and O_2 chemical reactions, with similar working fluids, hardware, maintenance, checkout, and overall technologies. These features result in the lowest-cost integrated EPS/RCS/ECLSS subsystem. The low cost derives from (1) shared development, (2) reduced hardware through shared redundancy, and (3) reduced logistics through shared contingency consumables. In addition, mission operational flexibility is improved by providing multiple success paths for critical functions (H_2, O_2 generation) and increased secondary performance through shared capabilities.

INTEGRATED SUBSYSTEMS



FEATURES

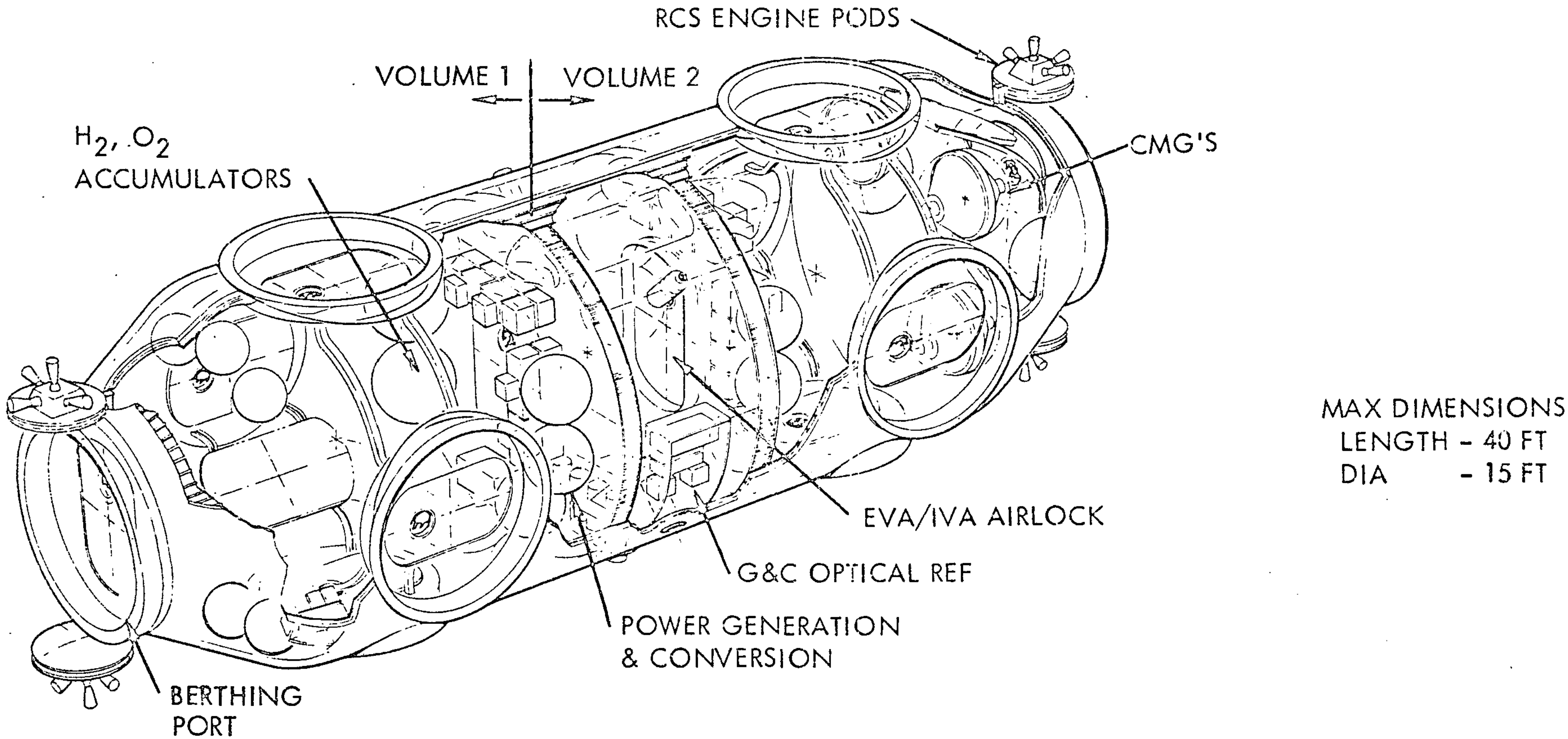
- HARDWARE & TECHNOLOGY COMMONALITY
  - DEVELOPMENT
  - MAINTENANCE
- INTEGRATED FUNCTIONS COMMON - BUILDUP, NORMAL OPS, EMERGENCY
- OPERATIONAL FLEXIBILITY - MULTIPLE SUCCESS PATHS
- REDUCED COST FOR DEVELOPMENT PLUS 5-YR OPERATION

CORE MODULE

The core module provides the main passageway between individual modules and contains the power generation, G&C, and RCS equipment. These subsystems are distributed between V_1 and V_2 volumes separated by the EVA/IVA airlock. The airlock is sized to accommodate two suited crewmen. All of the hatches open outward from the airlock. The EVA hatch (40-inch-diameter clear opening) is located at a 45-degree angle to provide the maximum clearance between the attached modules. The G&C optical reference and control-moment gyros (CMG's) are located on each side of the RAM berthing ports to provide the maximum pointing accuracy for the RAM's. All of the equipment is shirtsleeve-maintainable and-replaceable. Certain station buildup equipment is also accommodated such as antennas, thermal control radiators, RCS propellant, and initial power.

The module is 40 feet long with eight side berthing ports spaced 20 feet apart to provide the 5-foot clearance between modules as required for berthing or direct docking operations. A lightweight skin (0.040-inch aluminum) and stringer construction is utilized. Thermal covers are provided for the four side ports only (as oriented on this chart), with special insulation panels installed on the station module ports to provide thermal control during station buildup.

CORE MODULE



- ALL SUBSYSTEMS ON-ORBIT REPLACEABLE
- MODULE SPACING FOR DIRECT DOCKING OR BERTHING (5 FT)
- FIRST MODULE LAUNCHED - MINIMIZES COMPLEXITY OF POWER MODULE
  - REDUCES BUILDUP SCARS

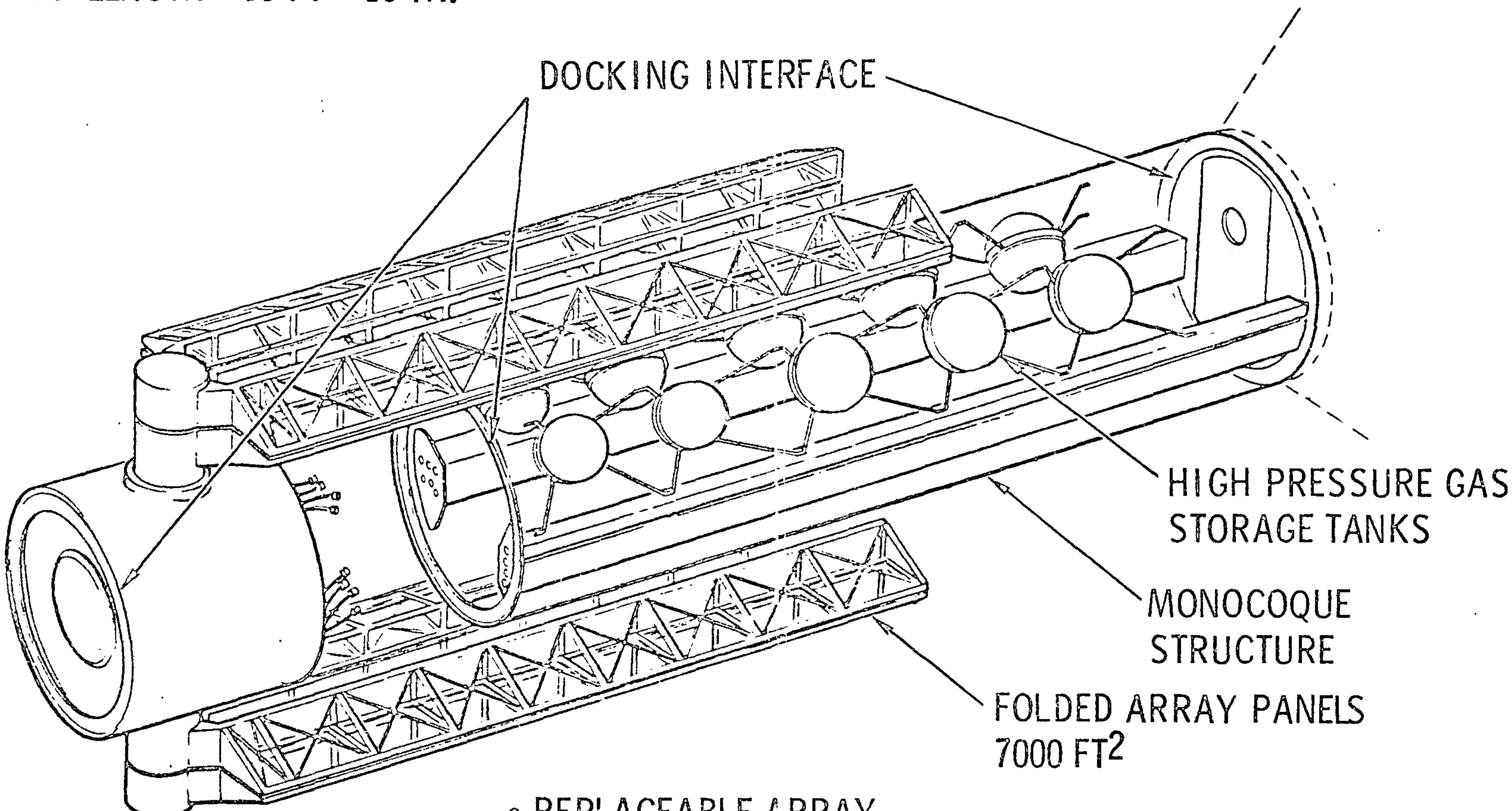
POWER MODULE

The power module consists of two assemblies, a power boom and a solar array. The solar array assembly consists of the arrays and an orientation drive and power transfer mechanism. Shirtsleeve maintenance of the mechanisms is provided. The solar array assembly is replaceable and utilizes the standard berthing port.

The power boom is 88 inches outside diameter by 27 feet, 6 inches long. The 88-inch-diameter boom allows the solar array panels to stow within the 15-foot-diameter shuttle payload envelope. The boom is of monocoque construction utilizing 0.145-inch-thick aluminum which increases its stiffness and consequently increases the natural frequency of the total space station assembly. High-pressure gas storage bottles for repressurization are placed in the boom. Shirtsleeve maintenance and replacement is provided even though the module is normally operated unpressurized.

POWER MODULE

OVERALL LENGTH - 33 FT - 10 IN.



- REPLACEABLE ARRAY
- NORMALLY UNPRESSURIZED
- ON-ORBIT REPLACEABLE EQUIPMENT

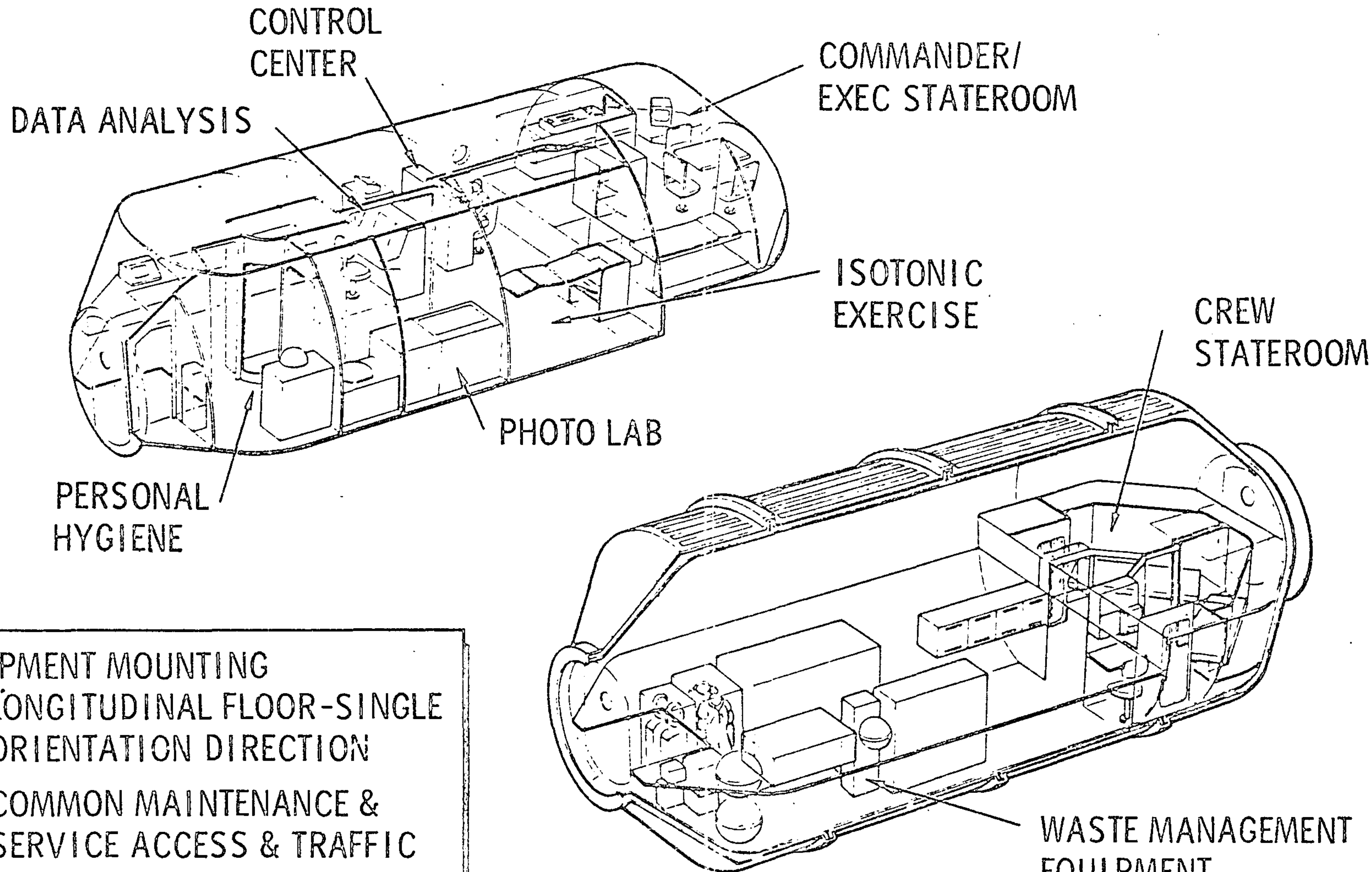
CREW/CONTROL STATION MODULE—SM-1

This module provides crew quarters for two crewmen below deck with the commander's/executive's quarters and office above deck. The hygiene facility including a shower is located at the opposite end of the module with control center No. 1 located adjacent to the commander/executive quarters. The remainder of the upper deck provides the data analysis and photo processing GPL functions and a backup medical facility and exercise area.

To simplify and minimize utility line lengths, the waste management equipment and computer memory rack are located directly beneath the hygiene facility and control center, respectively. Active thermal control equipment and EPS electrolysis equipment with general storage and PGA-PLSS facilities are the other major items located below decks. All of the equipment is maintainable and replaceable on orbit.

CREW/CONTROL STATION MODULES

STATION MODULE I



EQUIPMENT MOUNTING
- LONGITUDINAL FLOOR-SINGLE ORIENTATION DIRECTION
- COMMON MAINTENANCE & SERVICE ACCESS & TRAFFIC PATTERNS

CREW CONTROL STATION MODULE— SM-4

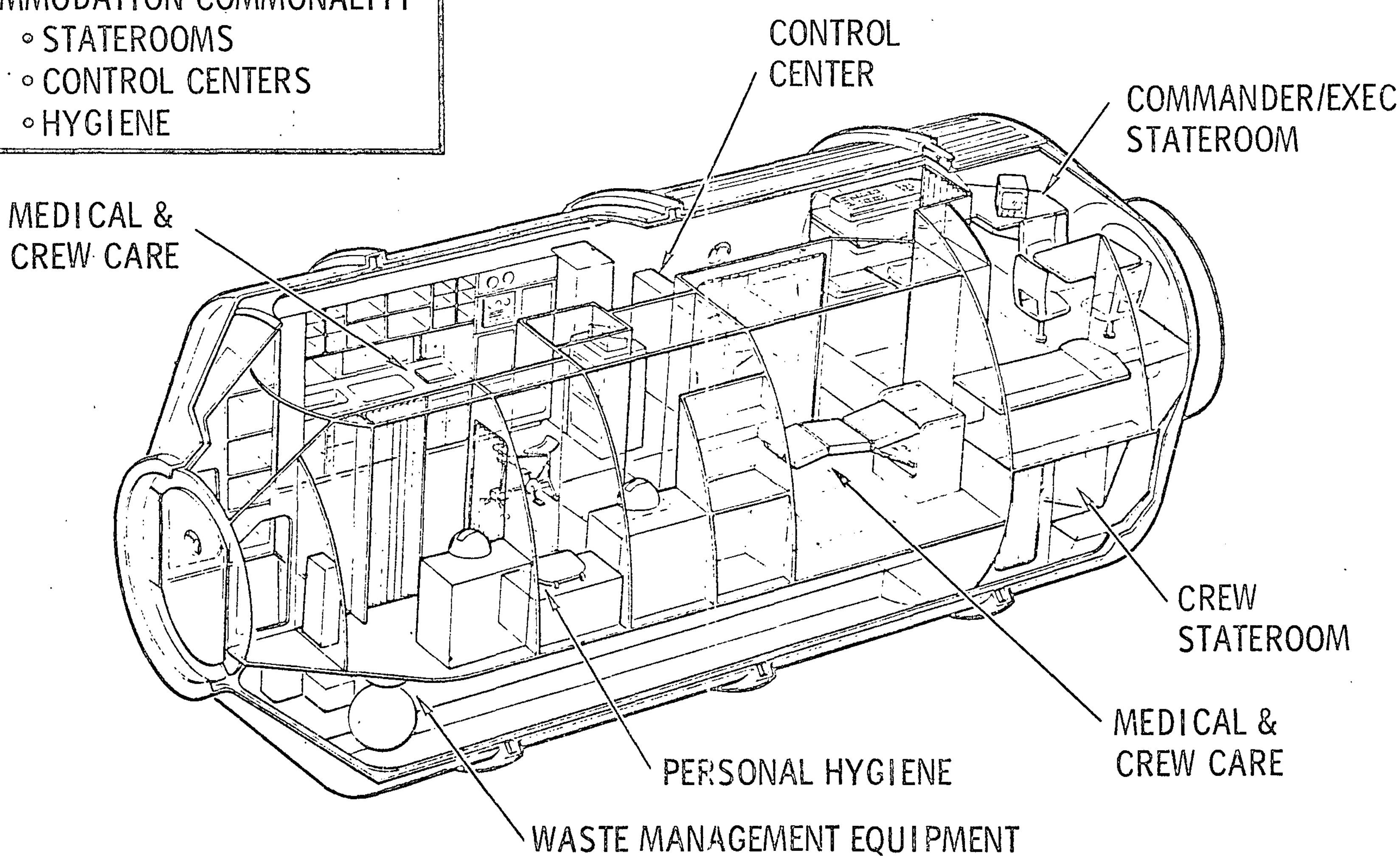
This module is essentially devoted to medical and crew care facilities. A medical examination and maximum care area is provided which can be isolated from the rest of the module. A crew qualification area containing the ergometer and lower body negative pressure and body mass measuring devices is provided. The remainder of this medical area is devoted to diagnostic use and medical supplies.

The two crewman quarters below deck, the commander's/executive's quarters above deck, control center No. 2, and the subsystem equipment below deck are all identical to the installation in SM-1. The personal hygiene facility in this module also is identical to that in SM-1 except for the omission of the shower unit.

CREW/CONTROL STATION MODULES

SM-4

- ACCOMMODATION COMMONALITY
  - STATEROOMS
  - CONTROL CENTERS
  - HYGIENE



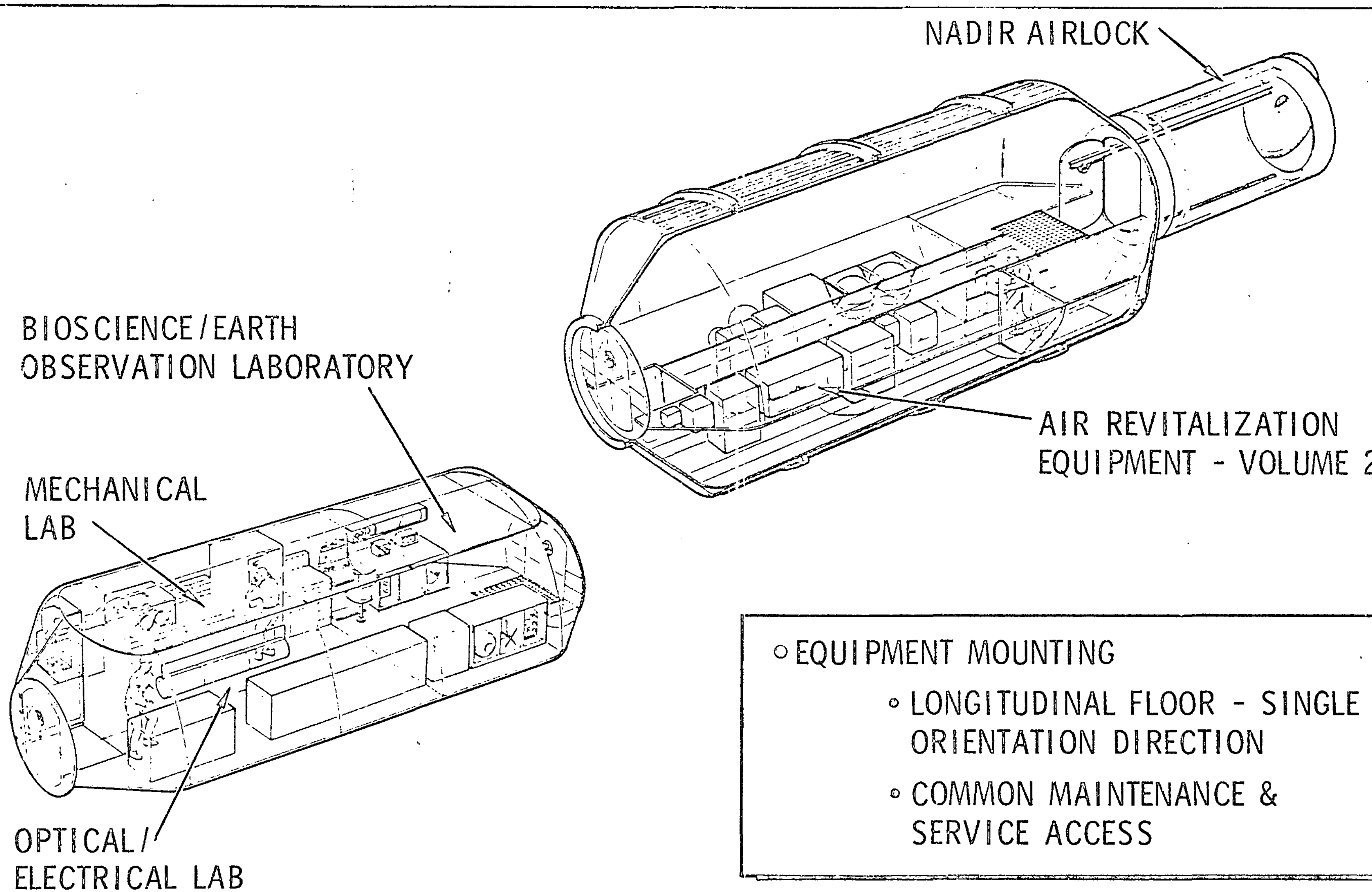
LAB/ECS STATION MODULE—SM-2

A nadir-looking airlock is attached to this module to perform bioscience experiments and earth observations. The area behind the airlock is utilized as an airlock loading, sensor stowage, and operations area. Additional experiment stowage is located directly beneath this area. Mechanical maintenance, electronic maintenance, and optical maintenance and calibration areas are the other GPL facilities located in the upper deck area. A backup galley area provides a minimum food preparation area for Volume 2.

The lower deck area contains the environmental control subsystem assemblies for air revitalization (CO_2 management and atmospheric control). Common installation arrangements provide easy access for maintenance and service.

LAB/ECS STATION MODULES

SM-2



- EQUIPMENT MOUNTING
  - LONGITUDINAL FLOOR - SINGLE ORIENTATION DIRECTION
  - COMMON MAINTENANCE & SERVICE ACCESS

LAB/ECS STATION MODULES—SM-3

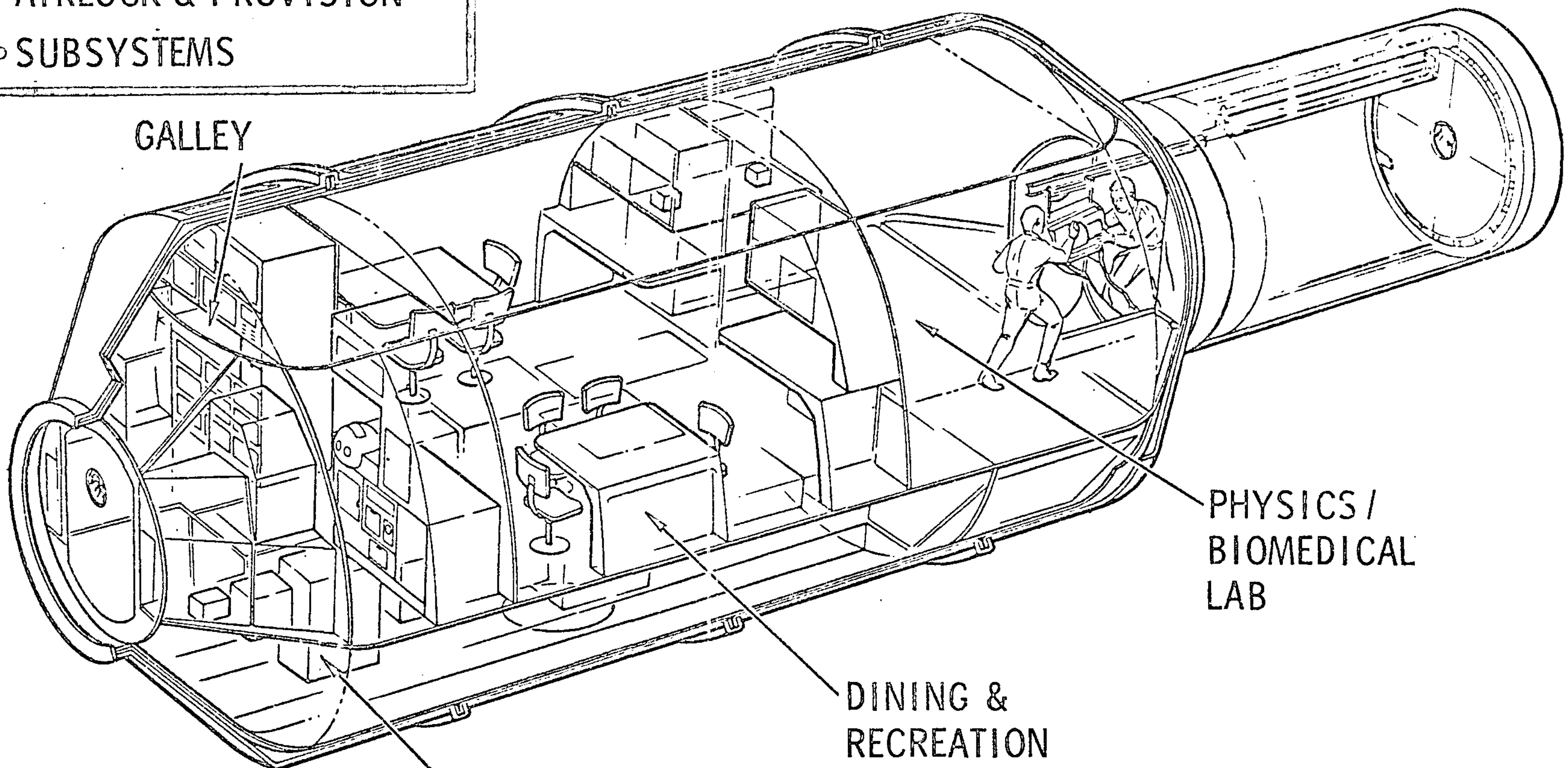
The above-deck area of this module contains the primary galley/dining and recreation facilities. The dining facility normally accommodates six crewmen but has the ability to accommodate 12. GPL facilities to accommodate both physics and biomedical experiments are provided. An airlock loading area to support the zenith-pointing airlock attached to this module also is provided in the upper deck area.

Identical air revitalization equipment in an identical arrangement as that described for SM-2 is located below deck. This module provides the air revitalization function for habitable Volume 1. An experiment stowage area also is provided in this lower deck area.

LAB/ECS STATION MODULES

SM-3

- ACCOMMODATION COMMONALITY
  - LABS
  - AIRLOCK & PROVISION
  - SUBSYSTEMS

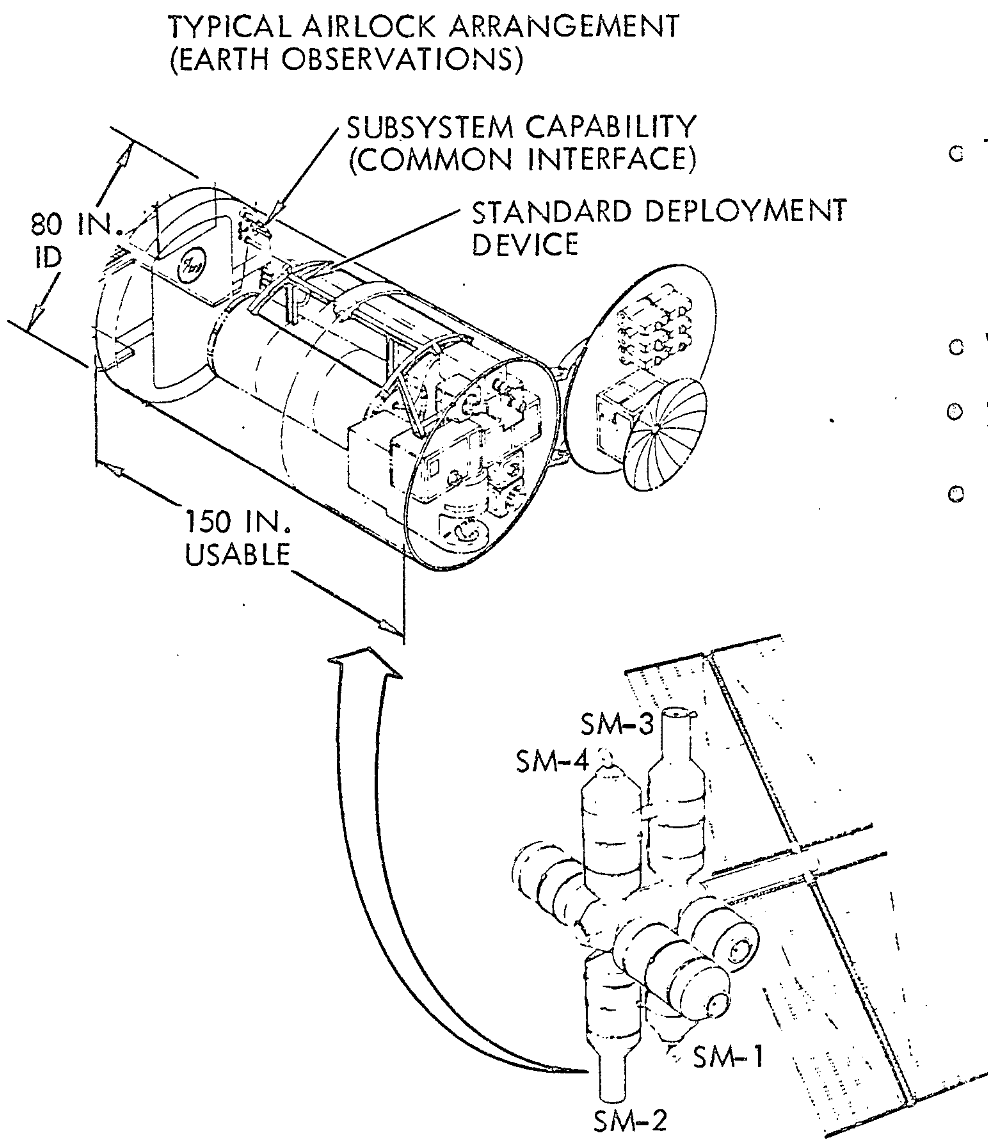


EXPERIMENT AIRLOCKS

Two experiment airlocks are provided as part of the GPL configuration to deploy scientific instruments to the space environment from the station pressurized volume. The nadir-pointed airlock is mounted to the end of SM-2 and the zenith-pointed airlock is mounted to the end of SM-3. The airlocks are mounted to the station modules with the normal station berthing system that provides mating, sealing, and utilities interfaces. The internal dimensions of the airlocks are 80 inches in diameter by 150 inches in length, providing approximately 436 cubic feet of usable volume.

The hatch window in the end of the station module is used for viewing the interior of the airlock from the pressurized volume. A standard window is provided in the hinged outer hatch for viewing EVA operations from within the airlock. The hinged outer door utilizes the station berthing system to lock and seal the airlock and is used to support experiment equipment. Both airlocks are pumped down into the station volume by station equipment and pressurized directly from the station atmosphere. Standard utility connections and deployment devices are provided for the airlocks.

EXPERIMENT AIRLOCKS



- TWO AIRLOCKS (REMOVABLE)
  - NADIR VIEWING
  - ZENITH VIEWING
- VOLUME 436 FT^3 EACH
- STANDARD DEPLOYMENT DEVICE
- COMMON DOCKING INTERFACE

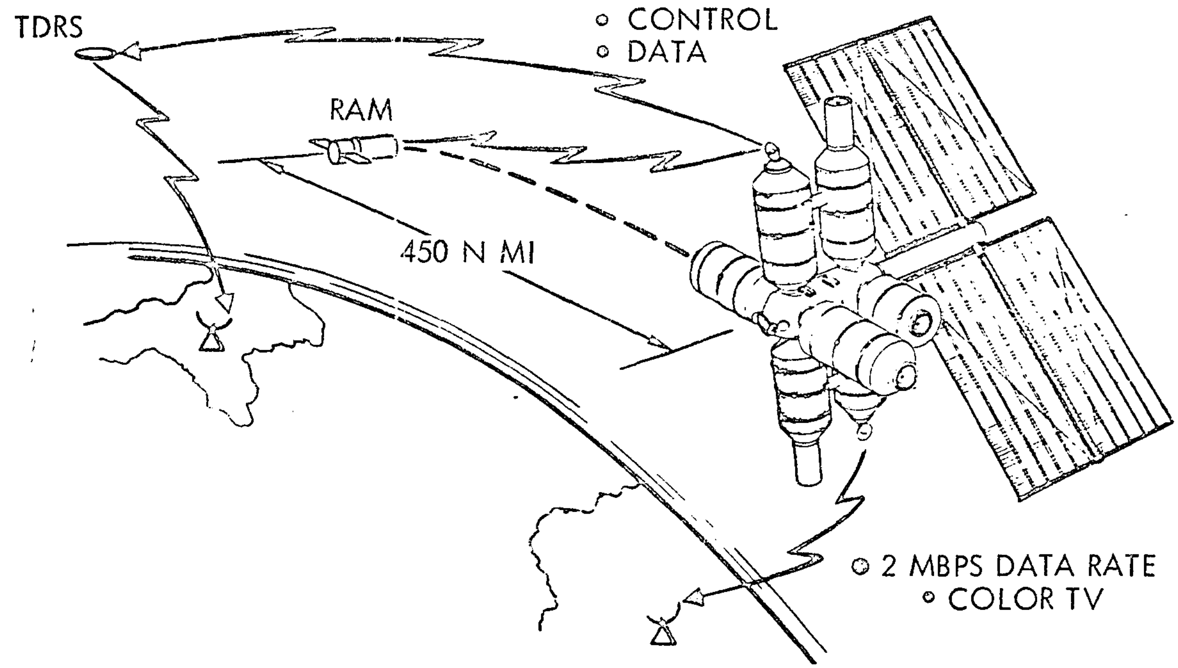
EXPERIMENT ACCOMMODATION SUMMARY

The MSS is an on-orbit facility in which space operations and scientific investigations are conducted. As such, the facility must have suitable features for conducting a variety of experiment programs.

The station provides the experiments with a very stable platform (maximum acceleration 0.01 g continuous - 0.00001 g for up to 2 hours). It also provides the capability for zero effluent dump (neither propulsive nor cabin venting) for a continuous 12-hour period in either of two modes, local level or inertial.

The required features were established following an analysis of the NASA Blue Book experiments and their attendant support requirements. The key requirements related to crew time, area, power, data processing, stability (acceleration, pointing), and logistics considerations. Crew time, skills, and area accommodation requirements were primary influences on the number and types of experiments which could be conducted on a time-phased basis. Where these influences were not a constraint, experiment scheduling was analyzed to establish nominal experiment support needs. Where experiment requirements imposed severe penalties to the design of the MSS, alternate means of satisfying the requirements were established. As an example, the earth observation multispectral scanner originally generated an extremely large amount of digital data (50×10^6 bps). This was a major impact on the MSS data bus, central processor, and communications equipment. An alternative scheme was derived which converted the output to analog form and handles in a manner similar to a TV signal.

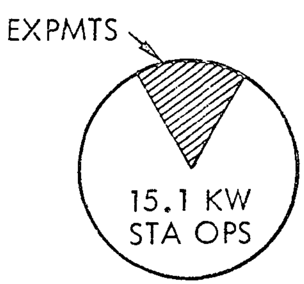
EXPERIMENT ACCOMMODATION SUMMARY



FLIGHT CHARACTERISTICS

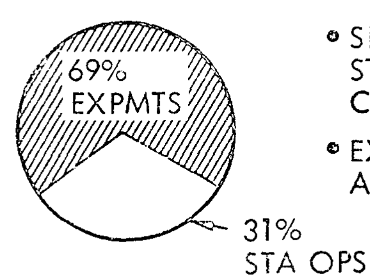
- DUAL FLIGHT MODE CAPABILITY
  - EARTH REFERENCE (LOCAL VERTICAL) ATTITUDE HOLD, GEOMETRIC AXIS HOLD
  - INERTIAL ATTITUDE HOLD
- NO DUMP (12 HRS)
- STABLE PLATFORM

ELECTRICAL POWER



- NOMINAL AVERAGE 4.5 KW
- 8.3 KW AVAILABLE DURING EARLY YRS
- 8.3 KW AVAILABLE WITH ADDED REACTANTS DURING LATER YRS

DATA PROCESSING



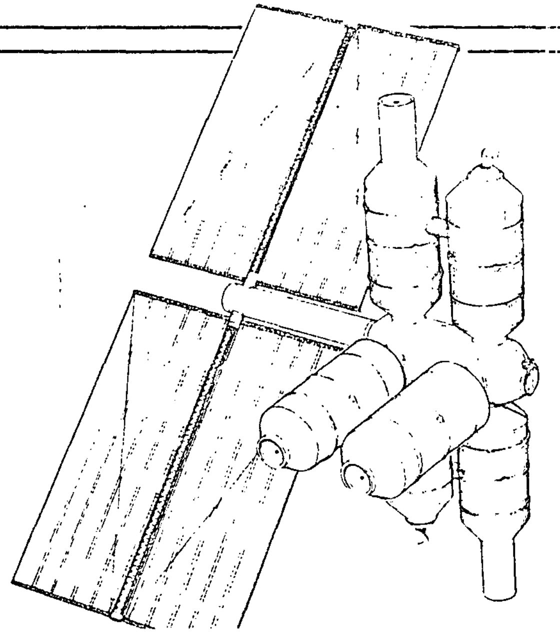
- SIMULTANEOUS STA OPS & EXPMT CONTROL
- EXPMT DATA ANALYSIS AREA

GROWTH FLEXIBILITY

There are several avenues of growth available beyond the six-man initial space station. One approach would be to add two common crew/lab modules on the RAM docking ports. This would provide 12-man capability with 1190 square feet of integral lab floor area but no RAM support provisions.

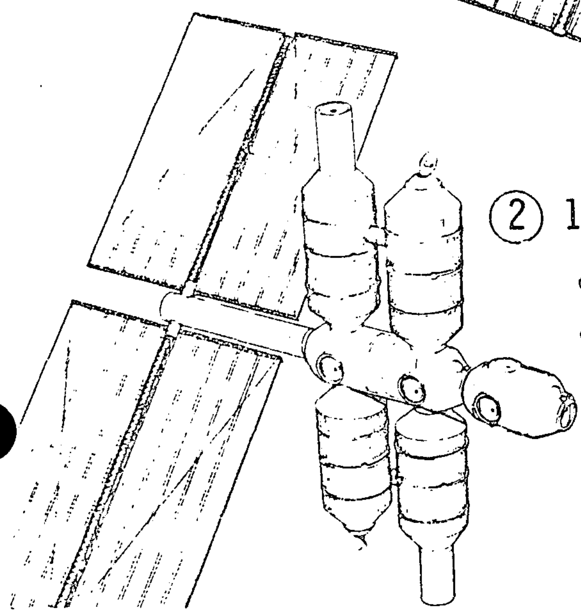
Another alternative would be addition of a "half core" to bring the total number of docking ports for RAM or tug support to six. The station could remain at six men or the existing habitability provisions could be expanded to support nine crew members. The full growth station as currently defined adds both the additional crew/lab modules and the half core, bringing the crew to 12 and making available four docking ports for RAM or tug support.

GROWTH FLEXIBILITY



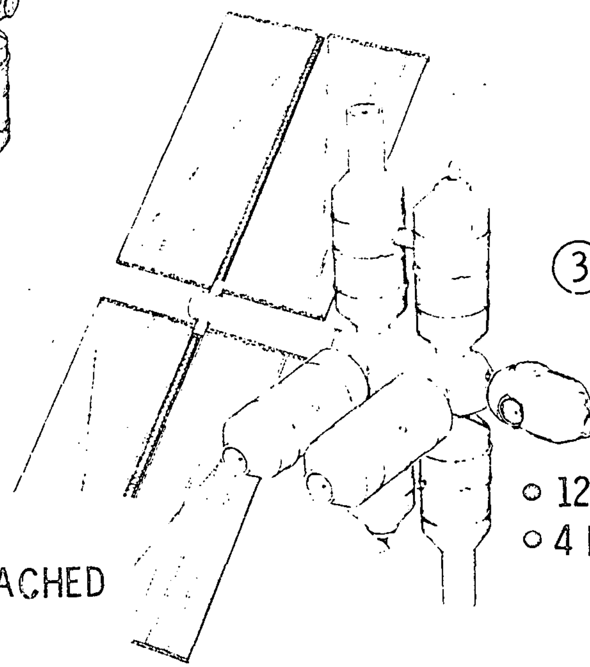
(1) COMMON CREW/LAB MODULES

- 12 MEN
- 1190 SQ FT INTEGRAL LABS
- NO ATTACHED RAM'S



(2) 1/2 CORE ONLY

- 6-9 MAN
- 6 DOCKING PORTS
  FREE FLYERS ATTACHED
  TUG SERVICE



(3) FULL GROWTH

- 12 MAN
- 4 DOCKING PORTS
  FREE FLYERS
  ATTACHED
  TUG SERVICE

MOCKUP STATUS - MOCKUP AREA AND EXTERNAL CONFIGURATION

The modular space station mockup is located adjacent to the 33-foot diameter space station mockup at the Seal Beach facility. The MSS mockup contains two of the station modules and a short section of the core module which connects the two station modules.

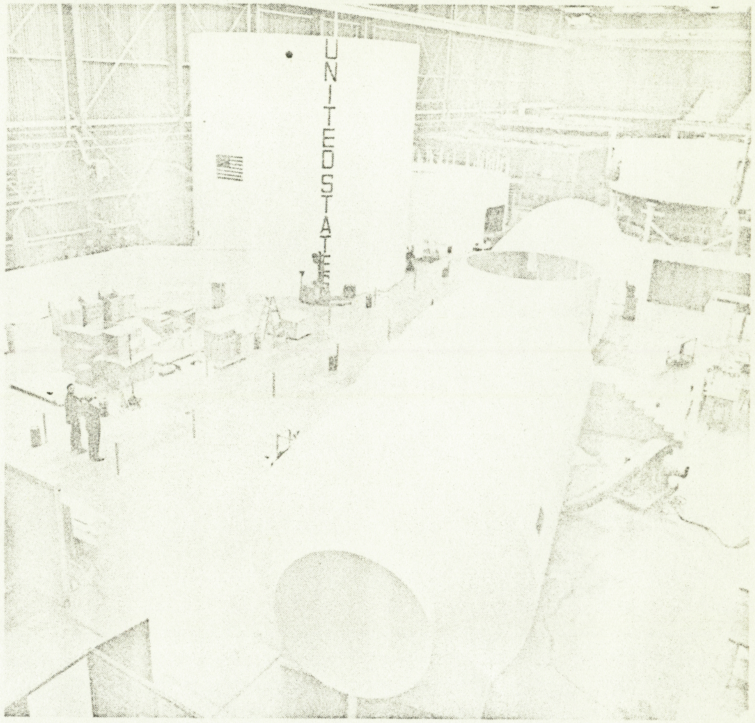
The modules selected for mockup are (1) a crew/control module (SM-1) and (2) a laboratory/ECS module (SM-2). The SM-1 module contains a commander's stateroom and two crew staterooms, a personal hygiene area, control center, data analysis laboratory, a photo lab, an exercise and backup medical area, and waste management equipment. The SM-1 mockup contains the ECS air revitalization equipment below deck and a large general-purpose laboratory on the upper deck.

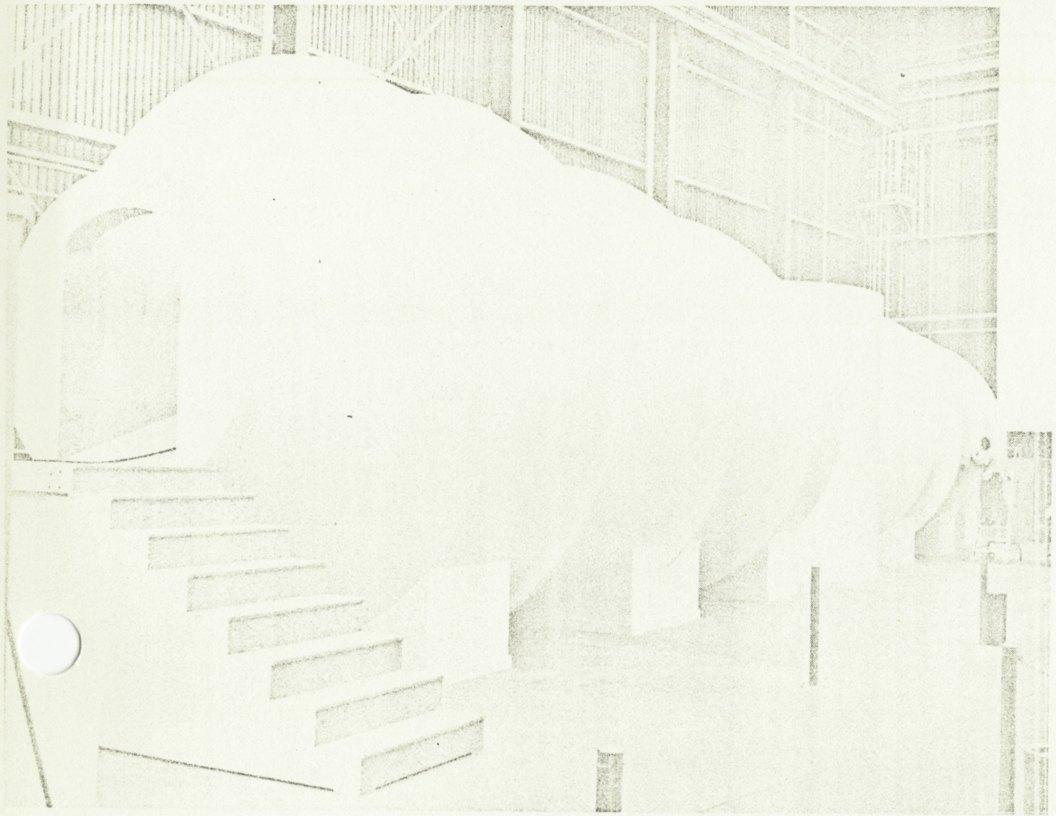
The mockup serves the purpose of assessing the MSS design features and emphasizes the overall habitability environment including functional furnishings and equipment concepts. In addition, the suitability of the configuration for routine housekeeping and station and equipment operations can be assessed.

MOCKUP STATUS

MOCKUP AREA &
CONFIGURATION
EXTERIOR

- MODULAR STATION - FOREGROUND
- 33 FT DIA STATION - BACKGROUND





MOCKUP END VIEW

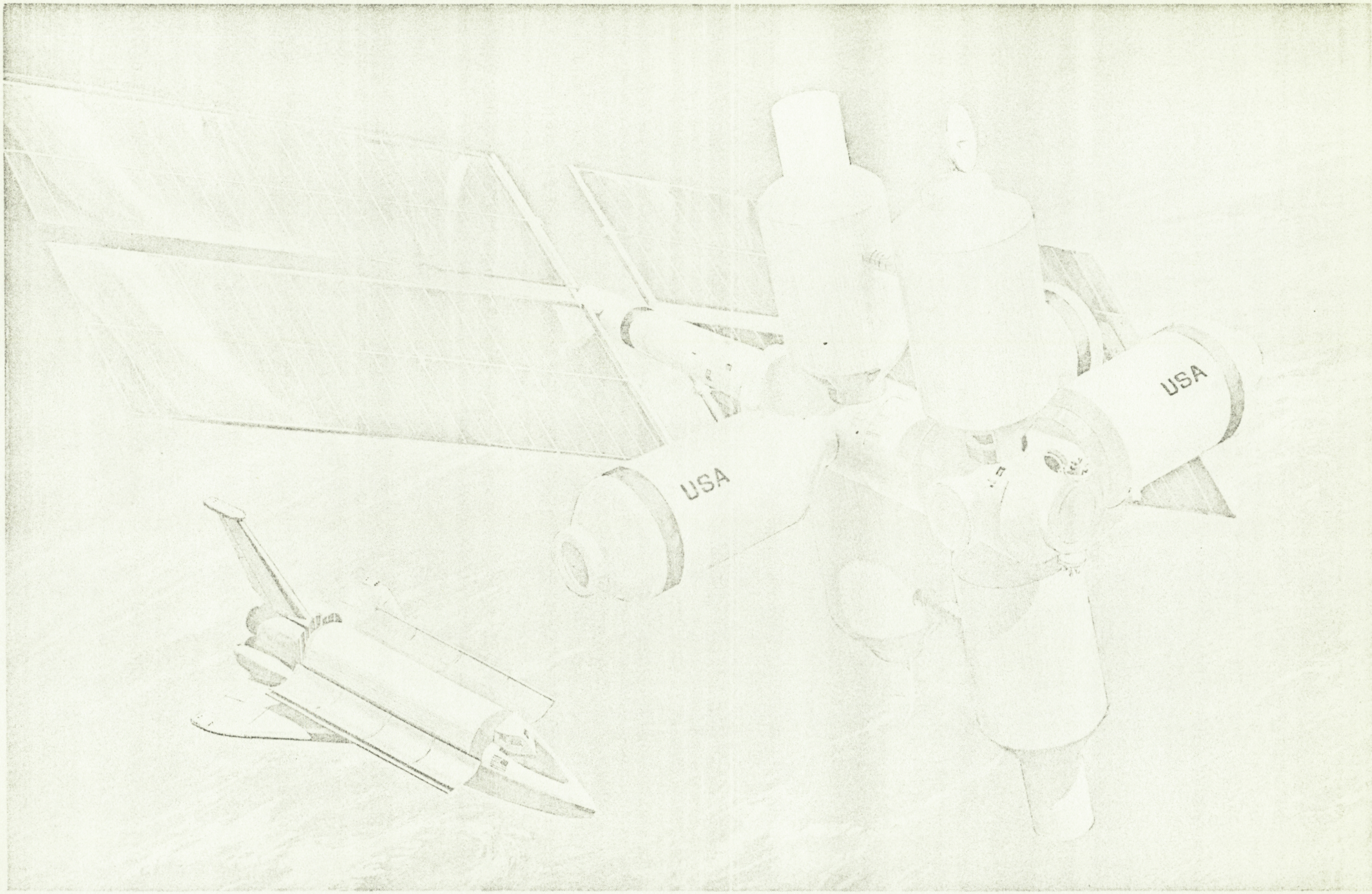
- SM-2 LAB/ECS MODULE ENTRANCE

MODULAR SPACE STATION

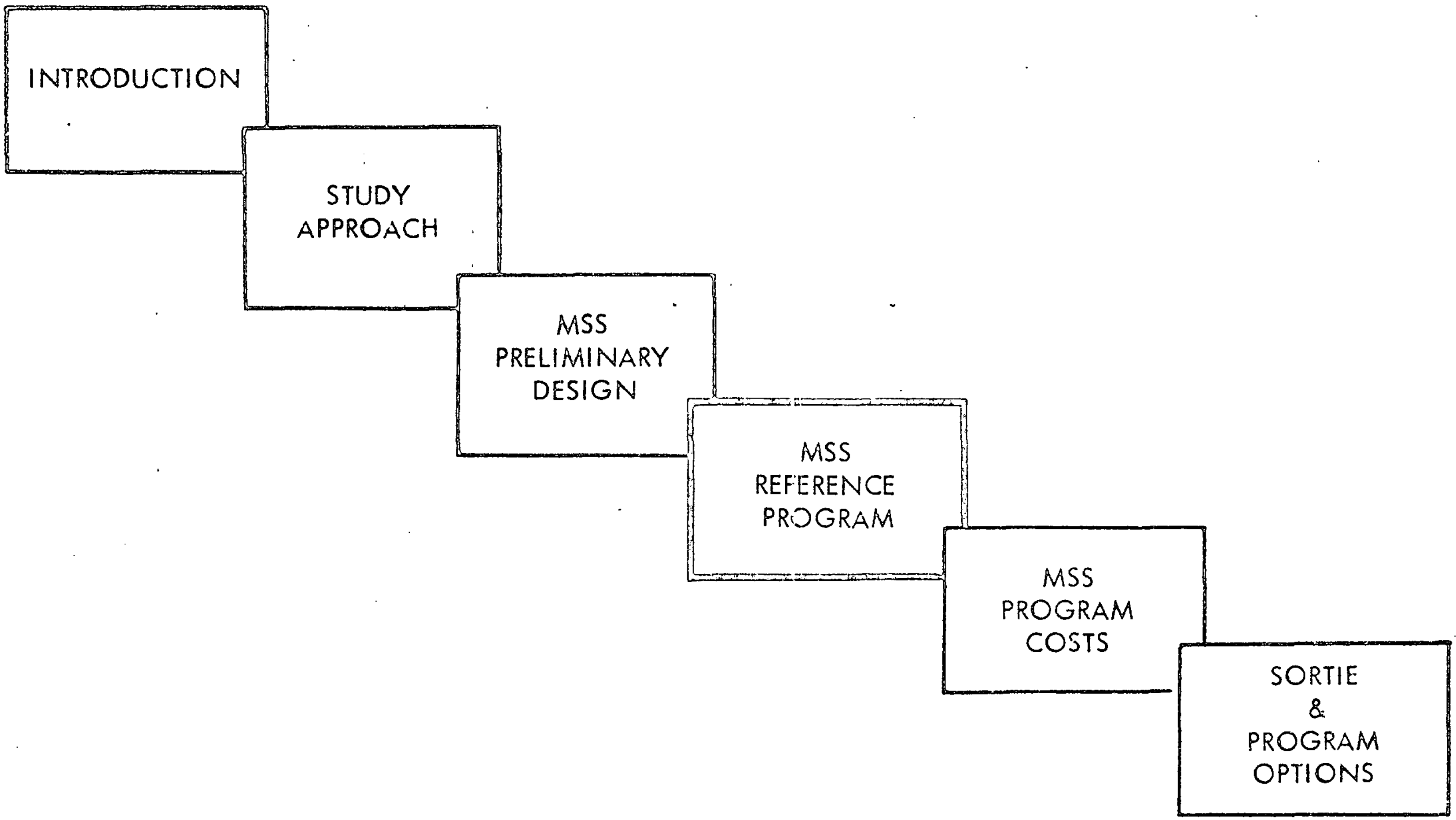
This chart is an artist's rendering of the initial modular space station in earth orbit. The station electrical power is furnished by the solar arrays shown deployed from a boom extending from the central core module. Four station crew, laboratory and control modules are shown attached to the core module in the vertical plane. Two are on the upper side with one zenith-pointing airlock and antenna package. The other two similar modules are attached on the lower side. Special-purpose experiment modules and a cargo module are attached in the horizontal plane.

The artist's rendering also shows a space shuttle arriving in the vicinity of the station. A new module is carried in the shuttle cargo bay for assembly to the station.

MODULAR SPACE STATION



MODULAR SPACE STATION PHASE B EXTENSION
NASA ADMINISTRATOR'S REVIEW



MISSION SEQUENCE PLAN

The mission sequence plan provides the time phasing of the program elements with emphasis on the scheduling of experiments. The mission sequence plan is summarized on the following series of four charts which present the experiment time phasing (length of bar), accommodation mode (by bar and module shading), and crew requirements (number of equivalent men per day symbols on bar). The experiment disciplines are presented in order in which the FPE's are introduced into the program.

The early FPE's in the physics and technology disciplines are precursor FPE's for measurement of the space station environment prior to the operations of external viewing FPE's such as earth observations and astronomy. The vertical dashed lines in 1987 represent the buildup phase to the growth space station in the experiment program.

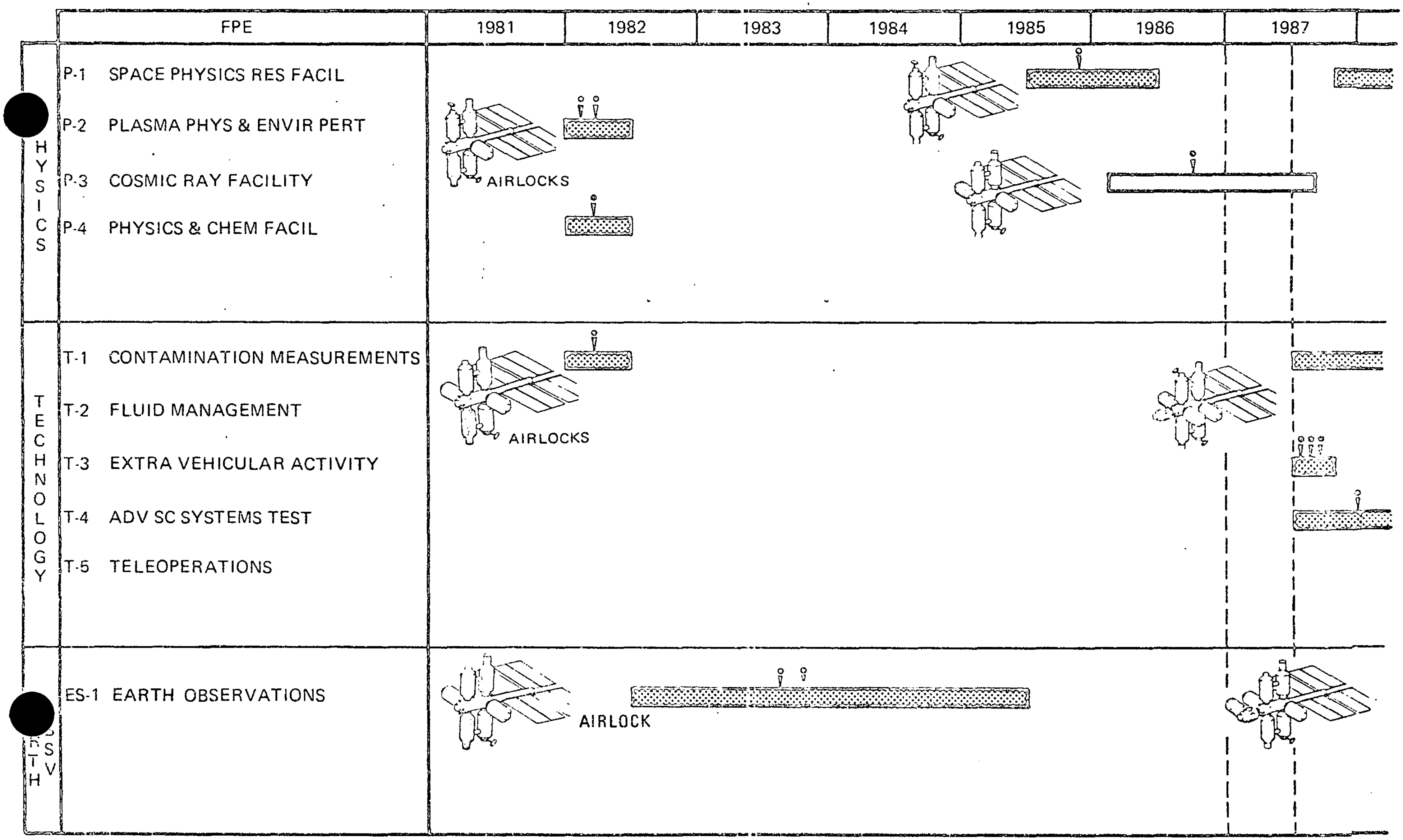
The mission sequence plan, as presented, was developed assuming each FPE is operated for one cycle at each level of activity (Level II and Level III). In the laboratory evolution philosophy, Level I refers to that portion of a total facility concept which supports experiments of short duration (example: sortie missions of 7 to 30 days). Emphasis at Level I is placed on applications and precursor type experiments.

Level II adds equipment associated with long duration or permanent-type experiments emphasizing a balanced but low-cost program. At this level, partial experiment laboratory capabilities are provided. Level III consists of the total Blue Book facility (i. e., complete laboratory experiment capability is provided for a specific discipline).

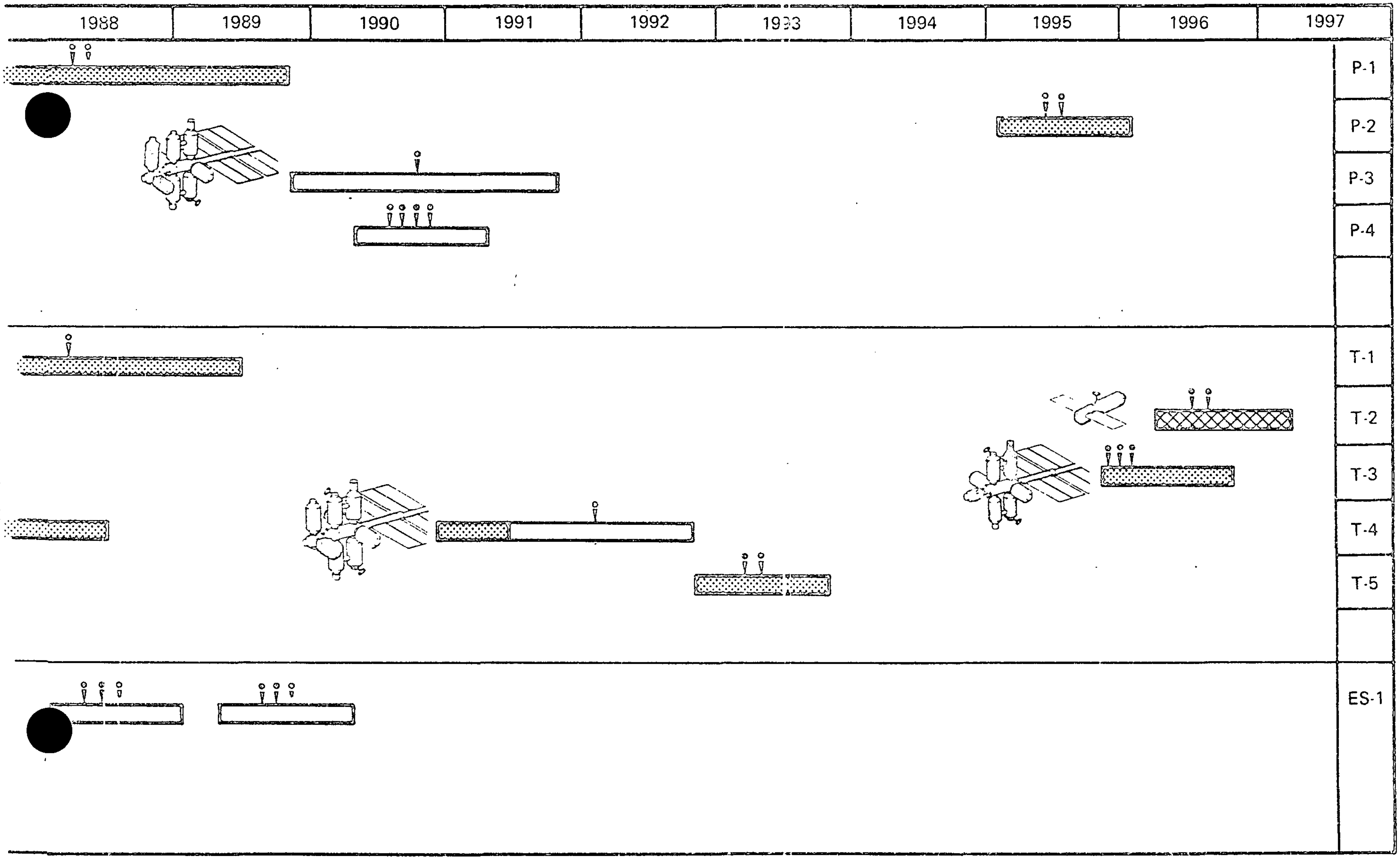
The first two charts show the experiment scheduling for the first three experiment disciplines (physics, technology, and earth observations) during the initial growth space station operational periods. Advanced spacecraft systems test (T-4) is shown evolving from a GPL/airlock facility (Level II) to include a RAM (Level III) in 1991. Also shown is the operation of a detached RAM for conducting fluid management experiments.

The resultant total program shown (including the other disciplines to be shown on the following charts), including buildup to the initial station and buildup to the growth space station, requires approximately 16 years to complete.

MISSION SEQUENCE PLAN



MISSION SEQUENCE PLAN (CONT)



MISSION SEQUENCE PLAN (CONT)

The four remaining experiment disciplines—astronomy, life sciences, material science, and communications and navigation—are presented on the next two charts. During the initial station period the first attached RAM is shown in operation in 1982 conducting high-energy stellar observations. The first detached RAM is accommodated in mid-1985 to conduct X-ray stellar observations.

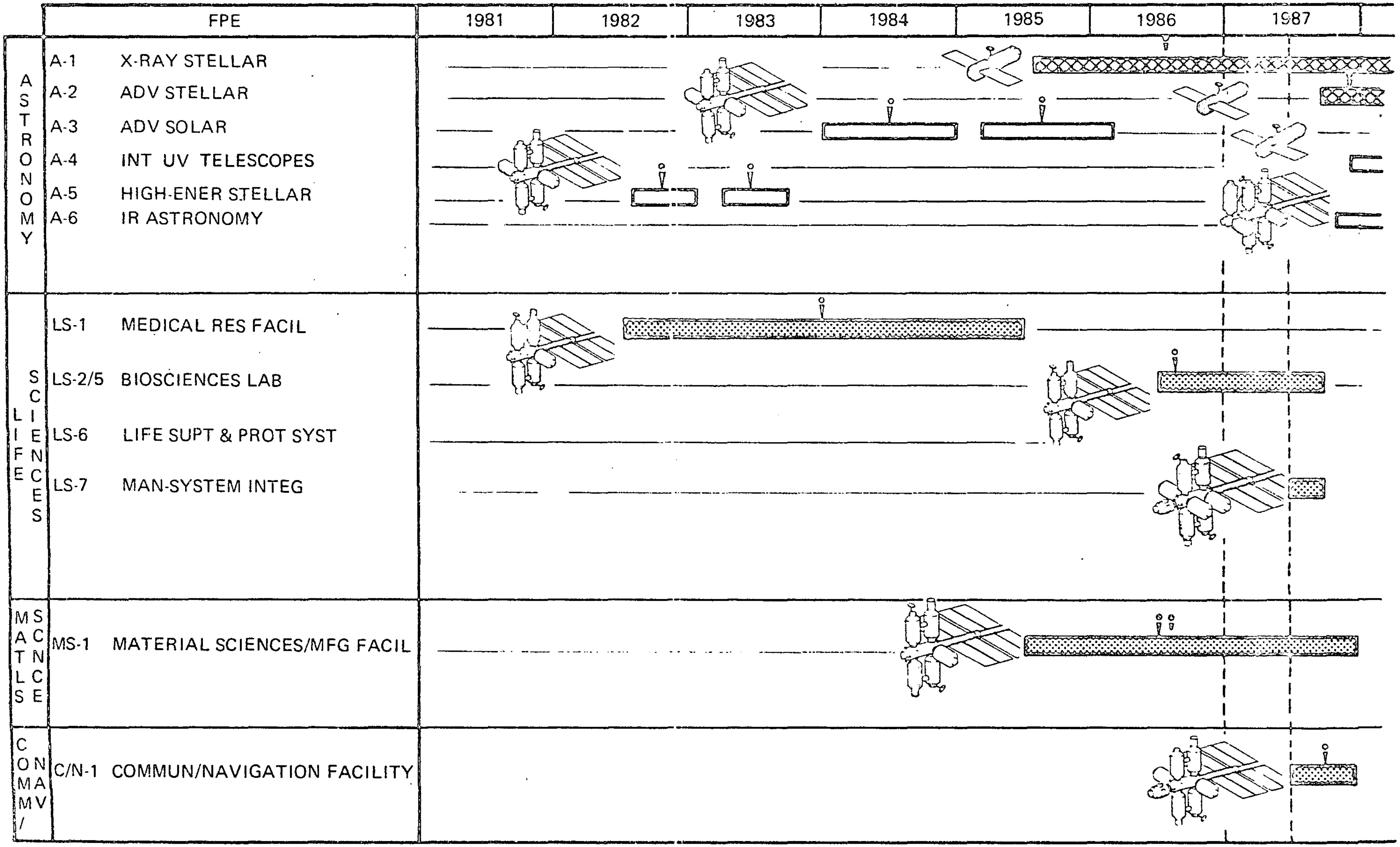
Not included in these summary charts are the logistics requirements. For the initial space station, approximately 1,900 pounds per month are required for basic station operations and 1,000 pounds per month are required to support experiment operations; a total of 2,900 pounds per month average. For the growth space station, approximately 3,600 pounds per month are required for station operations and 1,800 pounds per month are required for experiment operations, totaling 5,400 pounds per month average. The logistics capability for crew and cargo delivery is based on a cargo module payload capability of 11,800 pounds and remaining volume to deliver up to six crewmen.

The total shuttle support requirement is 35 flights for the initial space station and 99 flights for the growth space station. The resultant launch frequency is approximately one every eight weeks for the initial space station and one every six weeks for the growth space station.

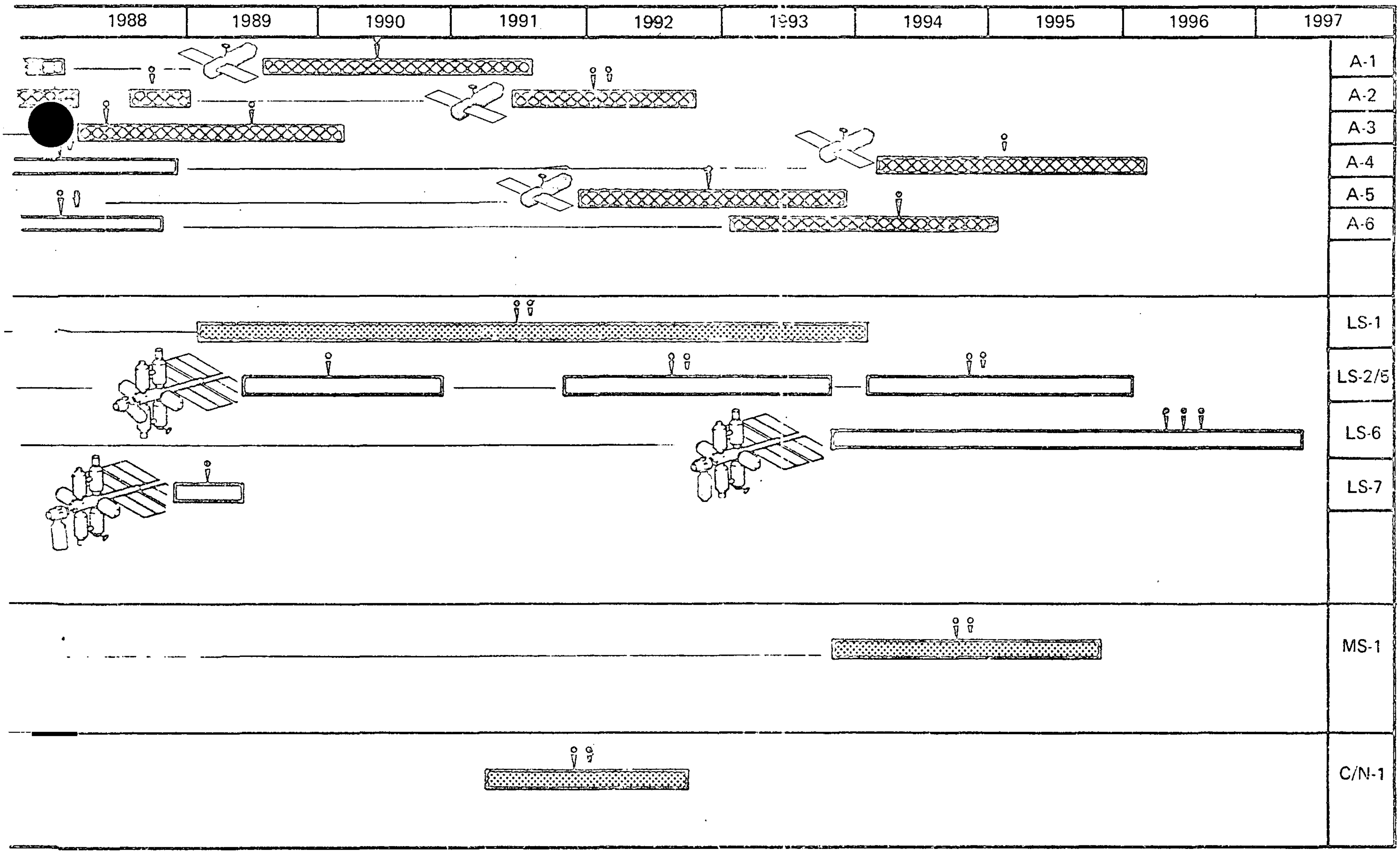
The mission sequence plan presented and the associated experiment scheduling is intended to be representative of the operations of the modular space station. It is not intended to represent the experiment program which must be scheduled since the space station has the inherent capability and flexibility to accommodate alternate programs (e. g., one which emphasizes socio-economic benefits or one which emphasizes advancements in scientific knowledge).

The plan is intended to emphasize certain fundamental characteristics, however. For example, by defining an initial level of experiment activity (Level II), the majority of the FPE's can be accommodated early in the program while deferring some of the experiment equipment development costs until after the space station development peak annual funding. In this respect, the plan illustrated the capability of the selected design concept to accommodate the Blue Bock in a balanced program in which all disciplines are represented throughout the program.

MISSION SEQUENCE PLAN (CONT)



MISSION SEQUENCE PLAN (CONT)

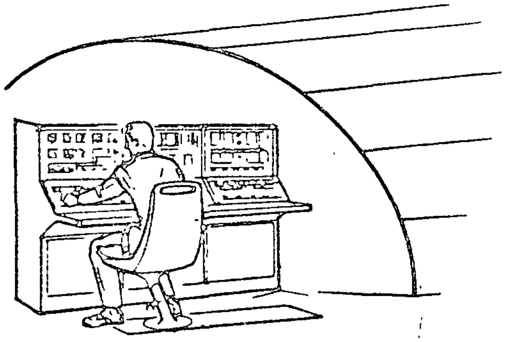


CREW REQUIREMENTS

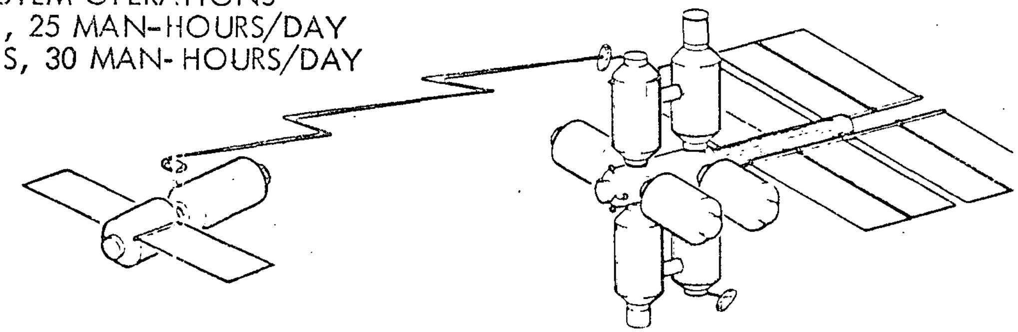
The crew requirements for station and support operations for the initial space station are on the order of 25 man-hours per day. These operations include the routine daily operations of the space station, routine and periodic maintenance, housekeeping, monitor and control of detached RAM's, etc. The experiment operations are those associated with the daily conduct of the space station experiments. Based on 25 man-hours per day for station and support operations and a six-man, 10-hour work day, approximately 35 man-hours per day are available for experiment operations for the initial space station. The corresponding crew time distribution for the growth space station is approximately 30 man-hours per day required for station and support operations, leaving 90 man-hours per day for experiment operations.

Twenty-seven crew skills have been identified for the conduct of experiment operations. In the early phases of the initial space station operations, only four skills are required for experiment operations, resulting in approximately 1.1 skills per crewman. During the remaining operations of the initial station, the average number of skills for experiment operations is eight, resulting in a requirement for approximately 2.4 skills per crewman. During the operations of the growth space station, between 11 and 19 skills are required, resulting in a requirement for approximately 1.7 skills per crewman.

CREW REQUIREMENTS



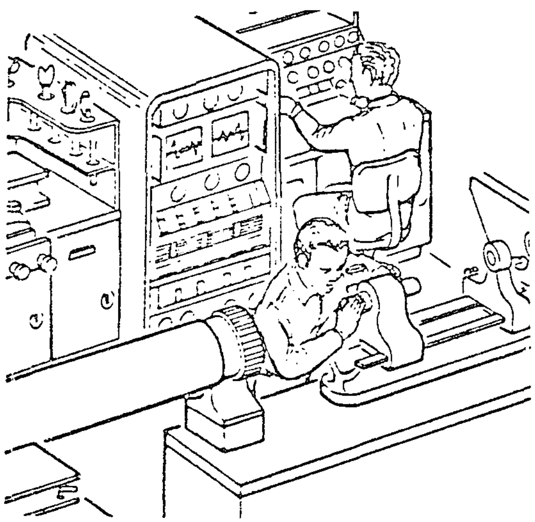
- SYSTEM OPERATIONS
  ISS, 25 MAN-HOURS/DAY
  GSS, 30 MAN-HOURS/DAY



STATION OPERATIONS

SUPPORT OPERATIONS

- APPLICATIONS & EXPERIMENT OPERATIONS



ISS - 35 MAN-HOURS/DAY | GSS - 90 MAN-HR/DAY

CREW NO.	1-3	4-9	10-14	15-16	17	18	19-21	22 23	23 24	24 25	25 26	26 27	27 28	28 29	29 30	30 31	31 32	33 34	34 35	36 37	37 38
DATE REQD	1/82	7/82	12/83	7/85	2/86	5/86	8/86	6/87	10/87	1/88	4/88	7/88	10/88	1/89	4/89	7/89	10/89	4/90	7/90	1/91	4/91
SKILL																					
1. BIOLOGICAL TECH		X	X	X	X	X	X	X	X					X	X	X	X	X	X	X	X
2. MICROBIOL TECH		X	X			X	X	X						X	X	X	X	X	X	X	X
3. BIOCHEMIST		X	X			X	X	X						X	X	X	X	X	X	X	X
4. ASTRON/ASTROPHYS															X	X	X	X	X	X	
26. AGRONOMIST										X	X	X	X	X	X	X	X				
27. GEOGRAPHER										X	X	X	X	X	X	X	X				
TOTAL NO. OF SKILLS	4	9	8	7	8	9	9	17	13	17	12	13	16	18	19	17	17	11	17	14	16
"AVERAGE" NO. OF SKILLS PER CREWMAN	1.1	2.4						1.7													

REFERENCE PROGRAM ELEMENTS

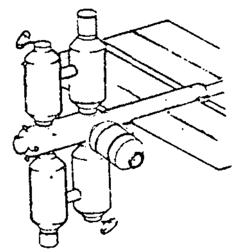
The initial space station consists of six basic modules: a core module, a power boom, and four station modules. A growth solar array, a short core, and two station modules are added to provide the basic capability of the growth space station.

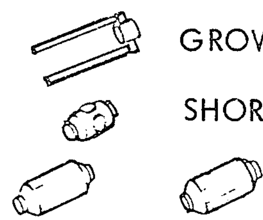
In addition to the initial and growth space station, the equipment necessary to support the experiment program must be provided. Thirteen Level II and 12 Level III experiment equipment groups are accommodated in the GPL which is integral to the stace station. (Level II identifies partial and Level III identifies complete laboratory experiment equipment groups.) Five Level II experiment equipment groups are accommodated in attached RAM's, whereas six groups (FPE's) are attached at Level III. Two detached RAM's are required at Level II and seven detached RAM's are required at Level III. By reconfiguring the Level II attached and detached RAM's, 13 experiment equipment modules will accommodate the experiment program. In addition, three support sections (which includes one spare) are required to support the detached RAM's identified in the experiment schedule.

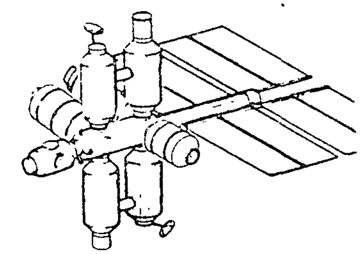
To provide the logistic support, three cargo modules are required plus the equivalent of one shuttle dedicated to the space station operations.

REFERENCE PROGRAM ELEMENTS

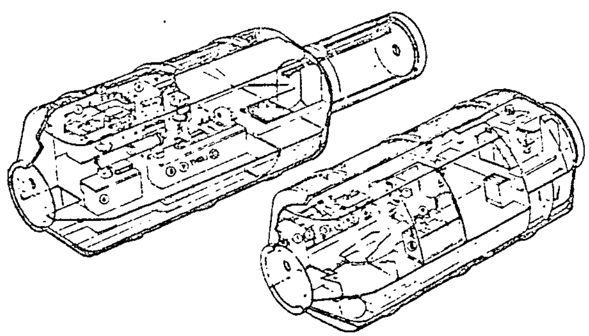
SPACE STATION

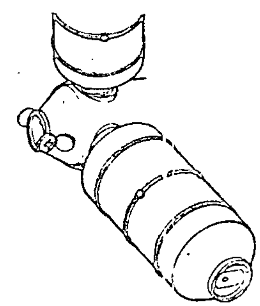

INITIAL STATION

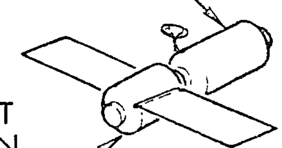



GROWTH STATION

EXPERIMENTS, EQUIP. ACCOMMODATION

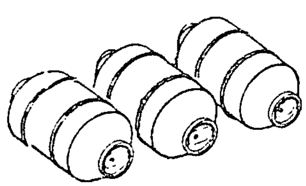

INTEGRAL

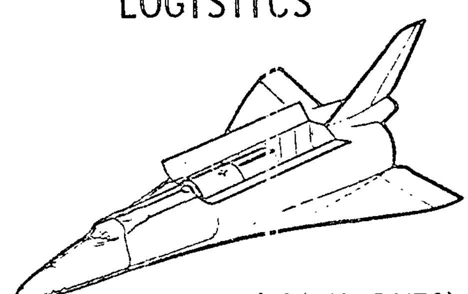

ATTACHED (6 MODULES)



DETACHED (7 MODULES)

LOGISTICS


3 CARGO MODULES


SHUTTLE (134 FLIGHTS)

- ORBITER (1) *
- BOOSTER (1)*

* (NORMAL OPS)

MODULAR SPACE STATION PHASE B EXTENSION

NASA ADMINISTRATOR'S REVIEW

INTRODUCTION

STUDY APPROACH

MSS PRELIMINARY DESIGN

MSS REFERENCE PROGRAM

MSS PROGRAM COSTS

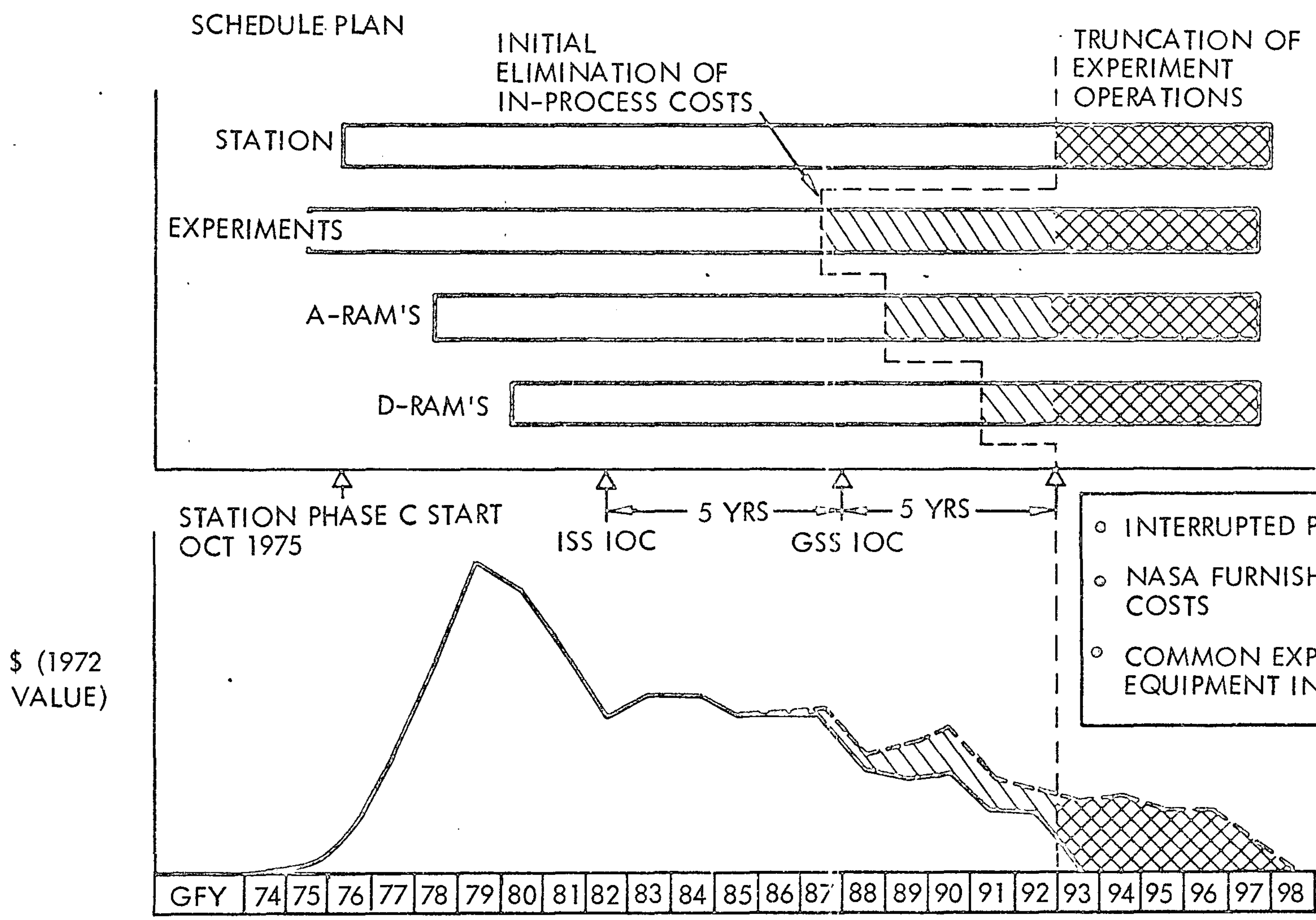
SORTIE & PROGRAM OPTIONS

BASELINE PROGRAM COST GROUND RULES

The cost and scheduling effort was directed to the areas of overall cost reduction and deferral of costs where possible. With Phase C start in 1975, shuttle technology is assumed to precede station. The initial station IOC is scheduled for GFY 1982, with growth station IOC five years later, in GFY 1987.

The termination of the station program costs after five years of growth operations (end of GFY 1992) results in truncating on-going experiment operations. It also results in the elimination of in-process costs for experiments and RAM's which will not be operational by then. To provide a favorable funding profile, development and production of growth station modules, RAM's and experiment equipment are deferred until required by the mission sequence plan. Experiment costs shown in this report are based on NR estimates and interpretation of the cost data in MSFC ASR-PD-MP-71-1, dated April 1, 1971, provided by NASA. RAM costs are derived by similarity to station modules for structures and to subcontractor-furnished data for other subsystems. Costs have been reduced and cost redundancy eliminated by design and operations simplification wherever possible. The general-purpose laboratory is a prime example of eliminating cost redundancies by integration of common experiment equipment requirements into the GPL as part of station-provided functions.

BASELINE PROGRAM COST GROUND RULES



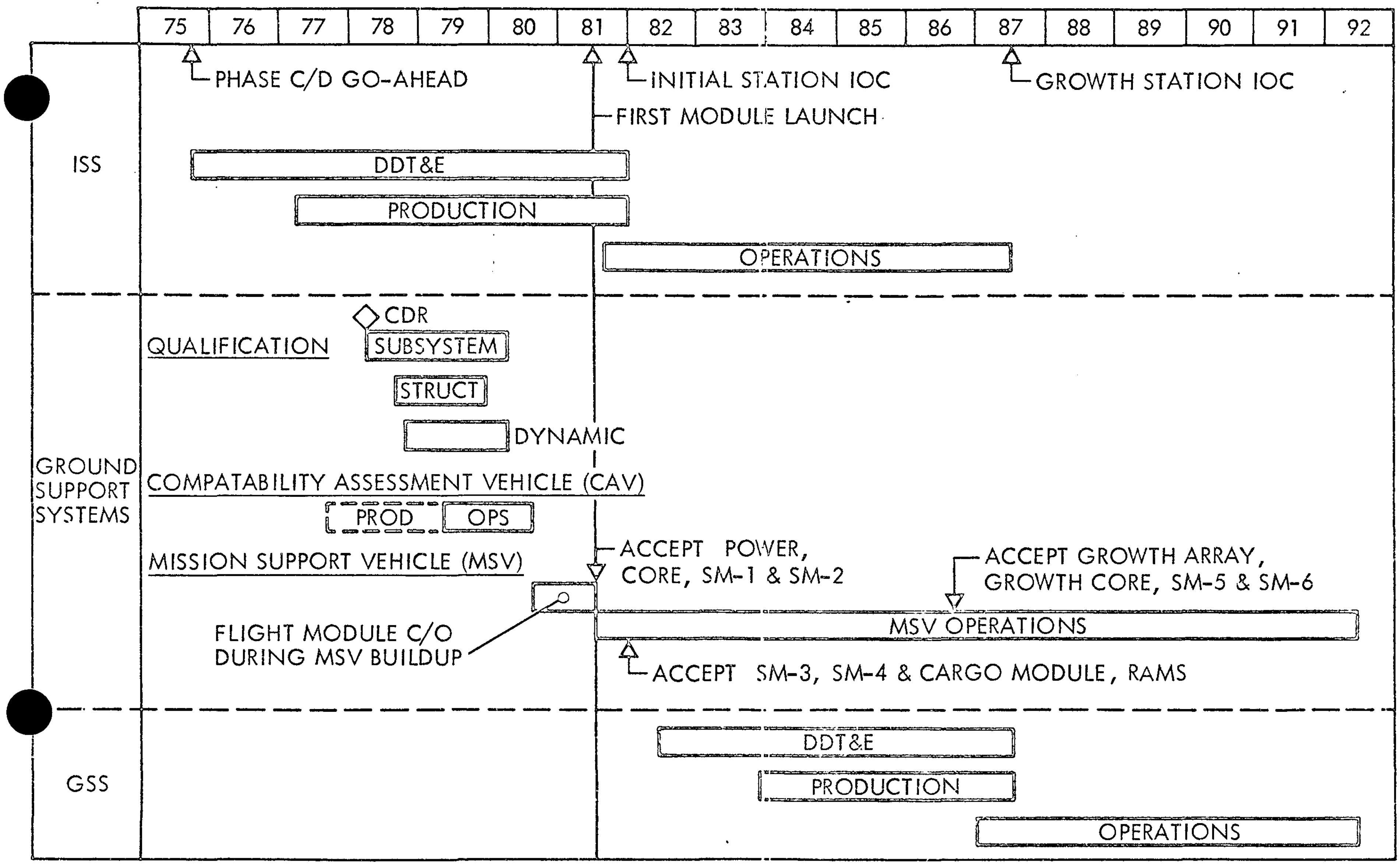
- INTERRUPTED PRODUCTION
- NASA FURNISHED EXPERIMENT COSTS
- COMMON EXPERIMENT EQUIPMENT IN GPL

BASELINE MODULAR SPACE STATION PROJECT SCHEDULE

This chart illustrates the relationship among key program milestones and the major ground support considerations for the initial and the growth space station development, production and operation. Phase C/D effort is initiated on October 1, 1975, with the first station module launch planned for July 1, 1981. The initial station IOC occurs seven months later on January 1, 1982, and is followed by an operations period ending with attainment of the 12-man growth space station on July 1, 1987. Growth station operations are then projected for a five year period ending June 30, 1992.

The program phasing which permits buildup of a mission support vehicle (MSV) from structural test, dynamic test, and compatibility assessment operations is clearly shown as supporting the first module launch of the initial station. The MSV will be in continuous operation from its use as an acceptance fixture for ISS modules through the growth station IOC and subsequent operations. To provide a favorable funding profile, development and production of growth station modules are deferred until required to support growth station buildup.

BASELINE MODULAR SPACE STATION PROJECT SCHEDULE



BASELINE PROGRAM FUNDING

The baseline program costs for the MSS are $5.978 billion. These costs are comprised of $2.804 billion for the space station project, and $3.174 billion for the experiments project. The costs for the experiments project contains four segments:

1. Integral Experiments - Experiments housed in the MSS GPL. These are the first experiments which are operational in the mission sequence plan. This cost segment (about 35 percent of total experiments) also includes the conceptual and definition activities associated with overall experiment planning and candidate payload definition. The major cost drivers are the earth surveys and life science experiments.

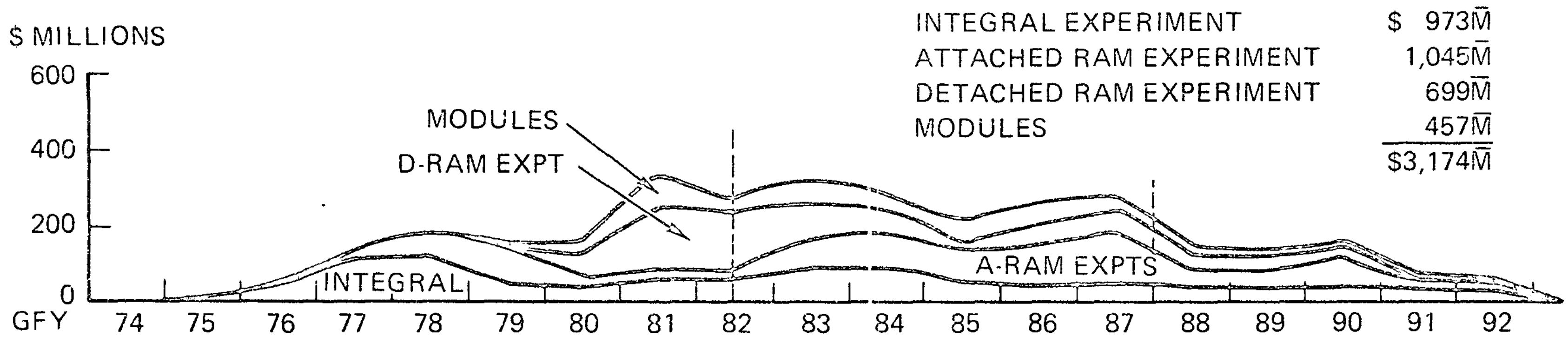
2. Attached RAM Experiments - These follow the integral experiments and are the largest segment of the experiment costs (about 40 percent) with astronomy and life sciences contributing most of the costs.

3. Detached RAM Experiments - About 25 percent of the experiment costs are in this segment and consist entirely of astronomy experiments in the baseline program.

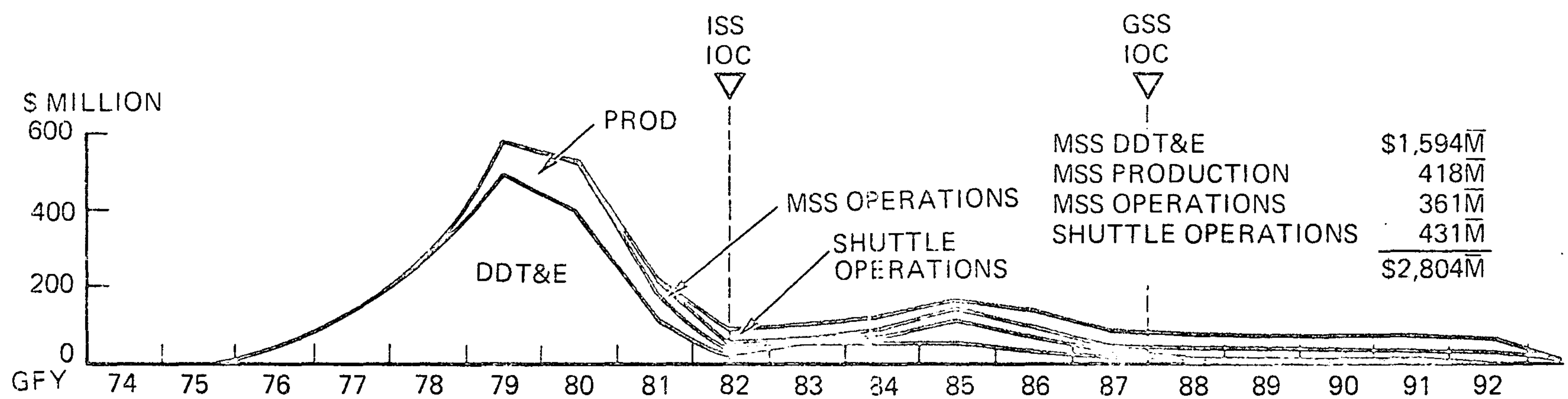
4. The experiment module segment, which is the cost associated with the development and production of the nine attached experiment modules, two detached experiment modules, three support section modules, and two modified attached experiment modules.

The MSS project element includes all of the costs required to design, develop, produce, and support the MSS. The MSS, with its crew and experiments, is capable of providing early benefit return and an experiment program for extended-mission durations. The MSS project element summarizes all lower-level elements identifiable and peculiar to the MSS (e.g., all modules, subsystems, module integration, spares, refurbishment, operations, and project management). Shuttle flight operation costs for station buildup and experiment operations are based on 96 flights according to the mission sequence plan.

BASELINE PROGRAM FUNDING



ANNUAL	9	52	140	196	149	152	318	276	311	295	208	256	272	137	122	148	63	70

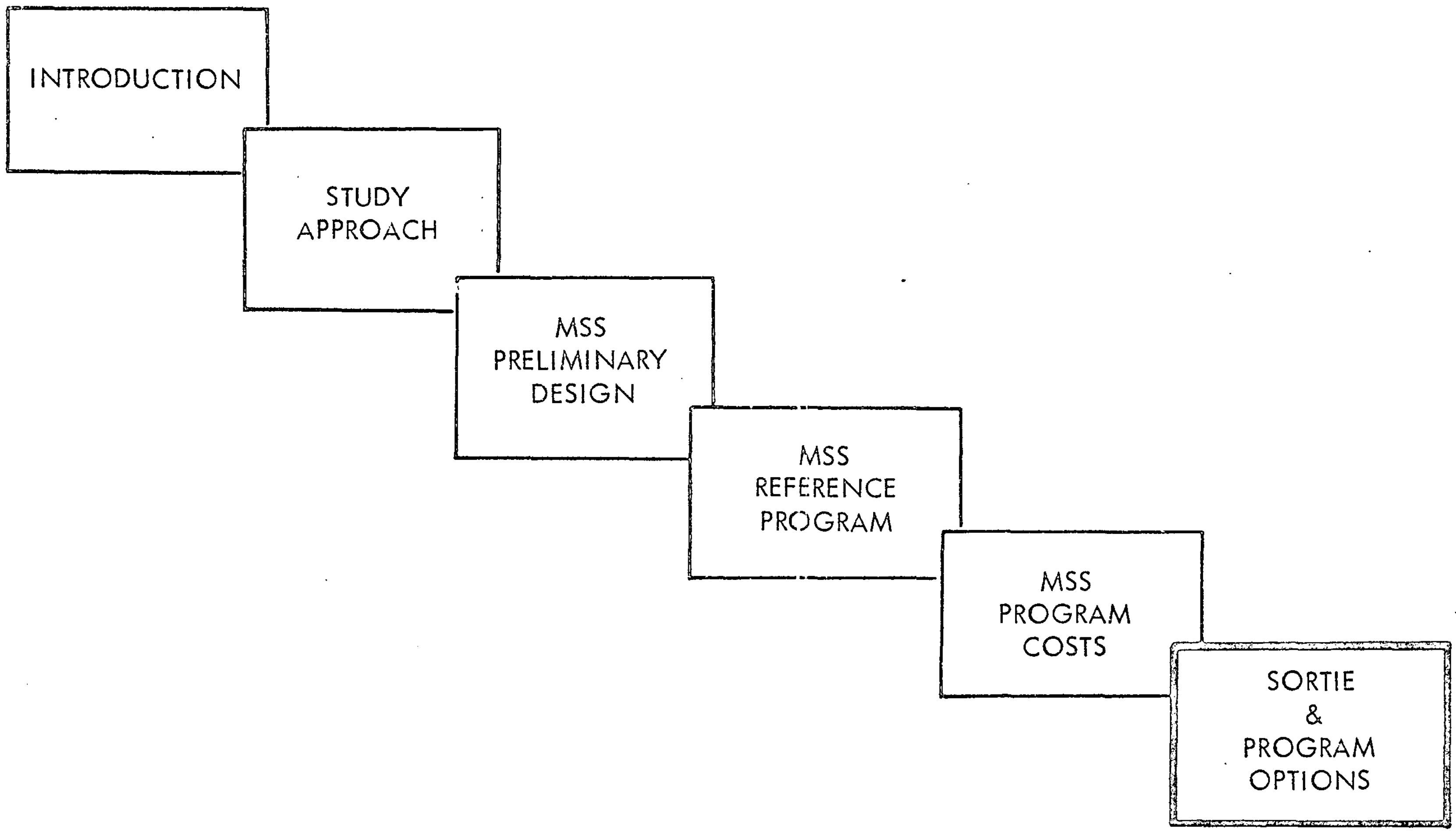


ANNUAL $M̄		35	126	278	578	516	204	87	100	113	162	117	91	88	82	73	82	72
TOTAL $M̄	9	87	266	474	727	668	522	363	411	408	370	373	363	225	204	221	145	142

TOTAL PROGRAM COSTS = $5,978M̄

MODULAR SPACE STATION PHASE B EXTENSION

NASA ADMINISTRATOR'S REVIEW



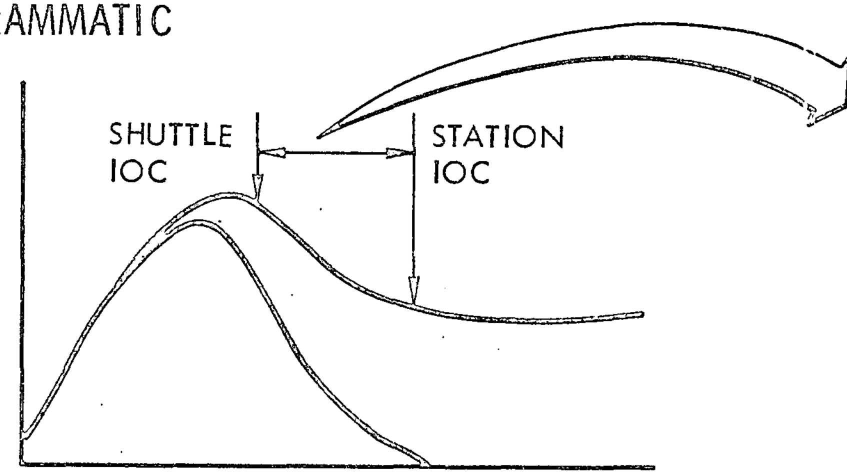
PURPOSE OF SORTIE ANALYSIS

The sortie analysis has two basic objectives: the identification of potential experiment payloads that are compatible with sortie mission characteristics, and the determination of commonality among these sortie payloads and the station or cargo modules and subsystems.

The phasing of space shuttle and space station programs to lower the combined funding peak creates a manned payload gap of three or more years. For experiments that can effectively be accomplished by a 7- or 30-day sortie flight, the shuttle sortie represents a viable approach. Further, the experiment equipment, subsystems, structure, and procedures could perhaps be common across many program elements including station modules, attached and detached RAM's, cargo modules, and the sortie modules.

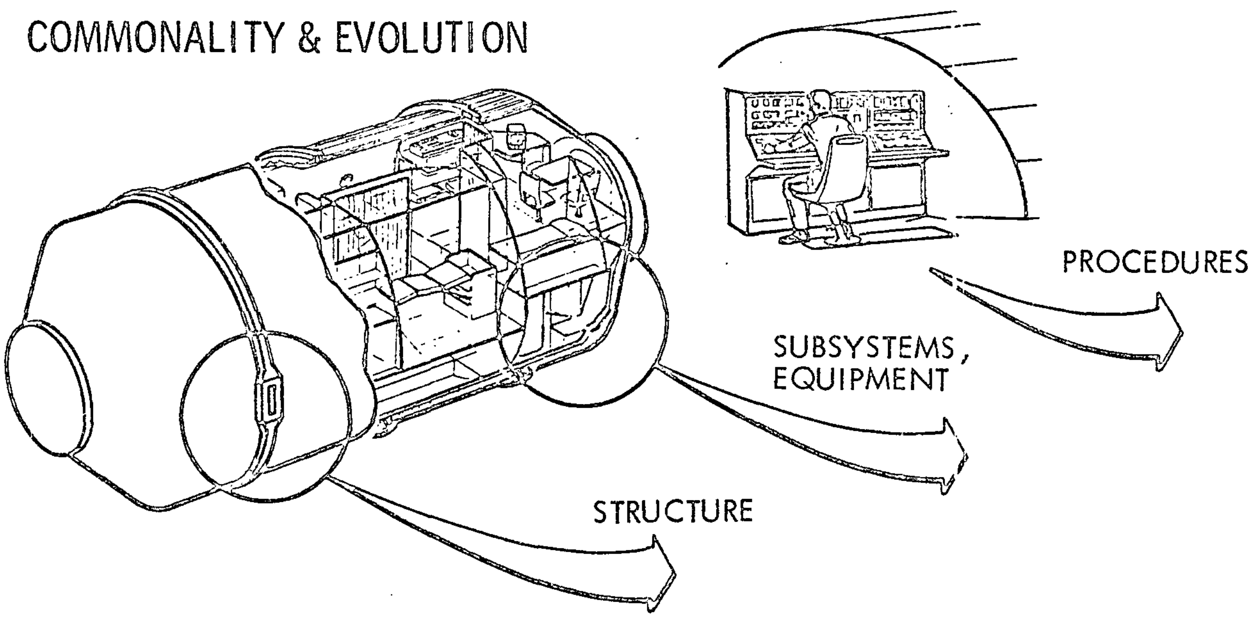
PURPOSE OF SORTIE ANALYSIS

PROGRAMMATIC



- IDENTIFY COMPATIBLE PAYLOADS
- EVALUATE MISSION EFFECTIVENESS
- DEVELOP CONCEPTS
- DEVELOP COSTS & SCHEDULE

COMMONALITY & EVOLUTION



- STATION MODULES
- ATTACHED RAM'S
- DETACHED RAM'S
- CARGO MODULES
- $\boxed{\text{SORTIE MODULES}}$

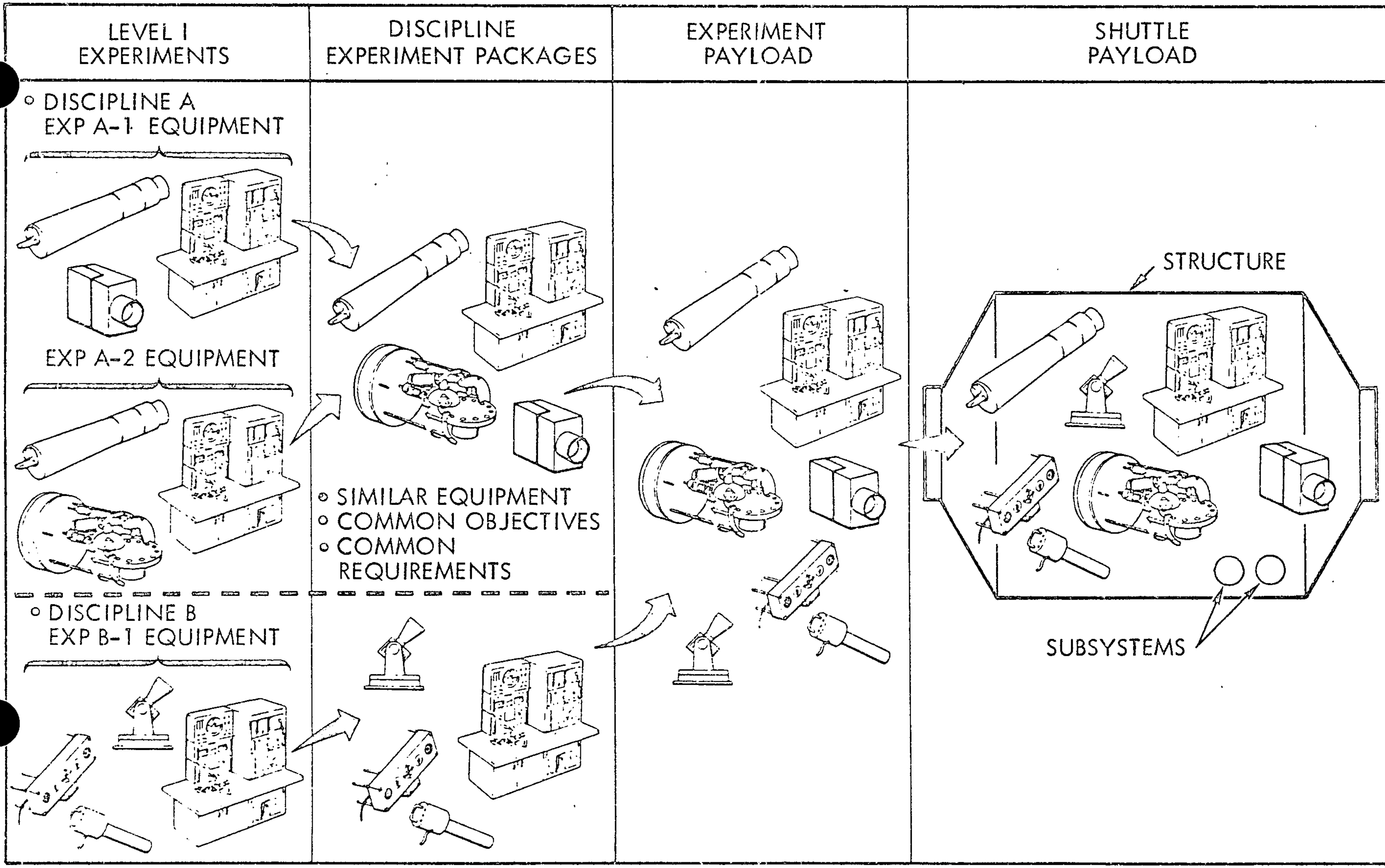
SHUTTLE SORTIE PAYLOAD DEFINITION

The sortie analysis conducted as part of the MSS study had two basic objectives: (1) identification of potential experiment payloads that can be carried by the shuttle during the 3-plus years between the shuttle's operational date and that of the station, and (2) determination of the commonality between the payloads and the station modules and subsystems.

NR's approach to the definition of shuttle payloads for sortie missions proceeded in the orderly fashion illustrated here. Experiments selected for Level I laboratories were extracted from the NASA 1971 Blue Book and were combined into sortie experiment packages which were commensurate with either 7-day or 30-day missions. The criteria applied to the combining process were those of common or similar equipment, objectives, and requirements among the individual experiments.

These packages were then combined into experiment payloads on the basis of their mission-related characteristics (i. e., orbits, crew skills, pointing, etc.). The support requirements were then determined and the accommodation mode (pallet or pressurized module) selected. The total set of support structure, subsystems, and experiment payload is the shuttle payload for a sortie mission.

SHUTTLE SORTIE PAYLOAD DEFINITION



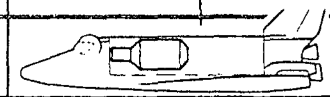
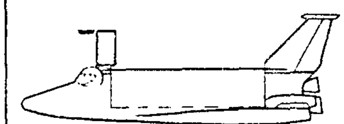
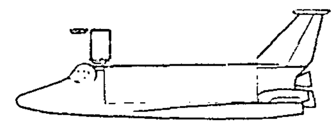
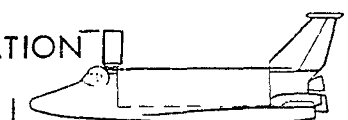
PAYLOADS AND ACCOMMODATIONS—7-DAY MISSIONS

This chart identifies the six payloads selected for 7-day missions. The experiment packages within each payload are also identified by number and title. The chart also illustrates the accommodation mode selected for each of the payloads.

Payloads 1 and 2 require the addition of habitable modules with Payload 2 also requiring EVA capability via the shuttle airlock. Payloads 3 through 6 utilize an MSS-type airlock, while Payload 5 also utilizes the airlock as a deployable pallet for sensor diredting.

Crew requirements can be met with two men (exclusive of the shuttle flight crew of two) with the exception of Payload 2 which requires a third man due to the EVA experiment. Power is supplied to the payloads from the shuttle's fuel cells; however, the payloads supply the cryogenic fuel. This fuel is stored in tanks located in the shuttle bay as part of each experiment package. From the standpoint of the experiment stability characteristics, Payloads 1 and 2 fall within the shuttle baseline capability. Payloads 3, 4, and 5 require the addition of stabilized platforms. Payload 6 requires a refinement of the shuttle's basic ACPS characteristic of 210 lb-sec minimum impulse to 40 lb-sec ACPS. This would be accomplished by the modification of the shuttle reaction control system.

PAYLOADS & ACCOMMODATIONS
7-DAY MISSIONS

PAYLOAD	EXPERIMENT PACKAGE	TITLE	ACCOMMODATIONS MODULE	 AIRLOCK	 PALLET
1	MS-III	MATERIALS SCIENCE			
2	LS3-II LS4-II T3-I	PLANT GROWTH CELLS & TISSUES ASTRONAUT MANEUVERING UNIT			
3	ES1-II T4-I T1-I	LAND USE MAPPING ADVANCED SPACECRAFT SYSTEMS TESTS SKY BACKGROUND BRIGHTNESS			
4	ES1-III T1-I	AIR & WATER POLLUTION SKY BACKGROUND BRIGHTNESS			
5	P1-I T1-I	ATMOSPHERIC/MAGNETOSPHERIC SCIENCES SKY BACKGROUND BRIGHTNESS		AIRLOCK AS PALLET	
6	P2-I P2-II	PLASMA WAKE PLASMA RESONANCES/HARMONICS	MAINT/ CALIBRATION ONLY		

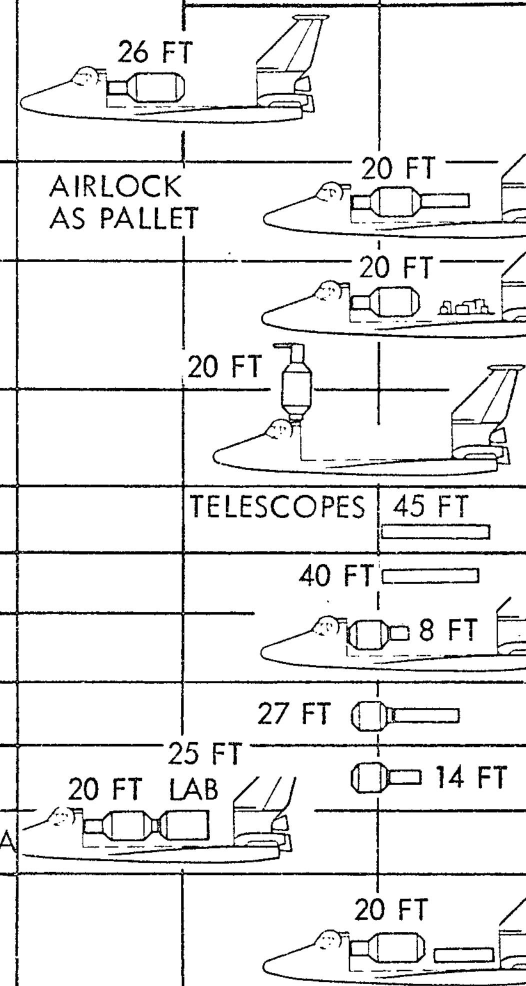
PAYLOADS AND ACCOMMODATIONS—30-DAY MISSIONS

This chart identifies the 11 payloads selected for the 30-day missions. The experiment packages, their names, and their accommodation are again identified for each payload. The length of the habitable modules that are required for each payload also is indicated.

Payload 1 requires a 26-foot module, while Payloads 2, 3, 4, 8, 9, and 10 utilize a 20-foot module, and Payloads 5, 6, and 7 utilize a 10-foot module. As mentioned previously for the 7-day missions, electrical power is supplied by the shuttle's fuel cells with the payloads being responsible for the fule. Also, Experiment Payloads 2 and 4 through 11 all require a stable platform, and Experiments 4 through 11 all require the lower minimum impulse level of 210 lb-sec for the ACPS engines.

PAYLOADS & ACCOMMODATIONS
30-DAY MISSIONS

PAYLOAD	EXPERIMENT PACKAGE	TITLE	ACCOMMODATION		
			MODULE	MOD/ AIRLOCK	MOD/ PALLET
1	LS1-I LS4-I } LS5-I } LS6-I LS7-II	BIOMEDICAL RESEARCH ROLE OF GRAVITY IN LIFE PROCESSES LIFE SUPPORT SYSTEMS DEVELOPMENT PERFORMANCE CAPABILITY ASSESSMENT			
2	P1-II P4-I	COMETARY PHYSICS MOLECULAR PHYSICS			
3	T2-I T2-II T2-III	LIQUID/VAPOR INTERFACE STABILITY BOILING HEAT TRANSFER CAPILLARY STUDIES			
4	ES1-1 T1-II	METEOROLOGY/ATMOSPHERIC SCIENCES REAL TIME CONTAMINATION			
5	A1-I	HIGH-RESOLUTION X-RAY TELESCOPE			
6	A3-I	PHOTOHELIOGRAPH			
7	A4-I	NARROW-FIELD UV TELESCOPE			
8	A5-I	LOW-ENERGY X-RAY TELESCOPE			
9	A6-I	DETECTOR ARRAY SCANNING			
10	P3-I	COSMIC RAY NUCLEI CHARGE/ENERGY SPECTRA			
11	C/N1-II C/N1-III	MILLIMETER WAVE COMM SYSTEM/PROP-AGATION SURVEILLANCE/SEARCH/RESCUE SYSTEMS			



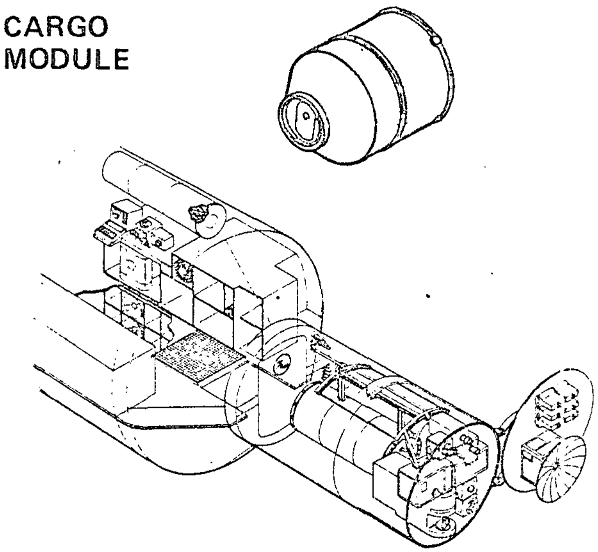
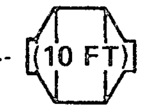
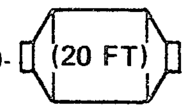
COMMONALITY ANALYSIS RESULTS

Commonality analysis was directed to accomplishing two primary objectives: commonality comparison for physical and functional characteristics of sortie and MSS subsystems and module configuration, and commonality comparison of the individual sortie payloads.

Three module configuration lengths would be required: 10, 20, and 26 feet long. Two module lengths could satisfy these requirements by mating the 10- and 20-foot modules to obtain the third module. The 20-foot module is a derivative of the MSS cargo module and is thus classified as 100-percent common. The 10-foot module is rated as 90-percent common due to the reduction in length of the constant diameter section. The MSS airlock concept can be used where an airlock is required and thus is rated as 100-percent common.

A few examples of the results of the subsystem commonality analysis are illustrated in the lower portion of the chart. For example, in the G&N subsystem, it was found that the star tracker assembly in 11 sortie payloads was 90-percent common to the MSS star tracker; the principal difference was in mounting provisions. Likewise, in the ISS, the MSS S-band communication assembly was found to be 100-percent common to those in 10 sortie payloads. Other components in the various assemblies were investigated and a few selected assemblies are indicated with their commonality to the MSS.

COMMONALITY ANALYSIS RESULTS

AREA	MSS ELEMENT	SORTIE ELEMENTS COMMON TO MSS	
		NO. PAYLOADS	% COMMON
STRUCTURE SUBSYSTEM	○ CARGO MODULE  ○ AIRLOCK	4-  10-  6	90 100 100
SUPPORT SUBSYSTEMS (ASSEMBLIES)	○ ASSEMBLY (EXAMPLES)		
	GUIDANCE/NAV		
	STAR TRACKER	11	90
	INFORMATION		
	COMM	10	100
	VIDEO REC	9	40 - 80
	ENVIRON CONTROL		
	FANS, RADIATORS, FREON PUMPS	17	80
	H_2O PUMPS, INTERCOOLERS	9	70

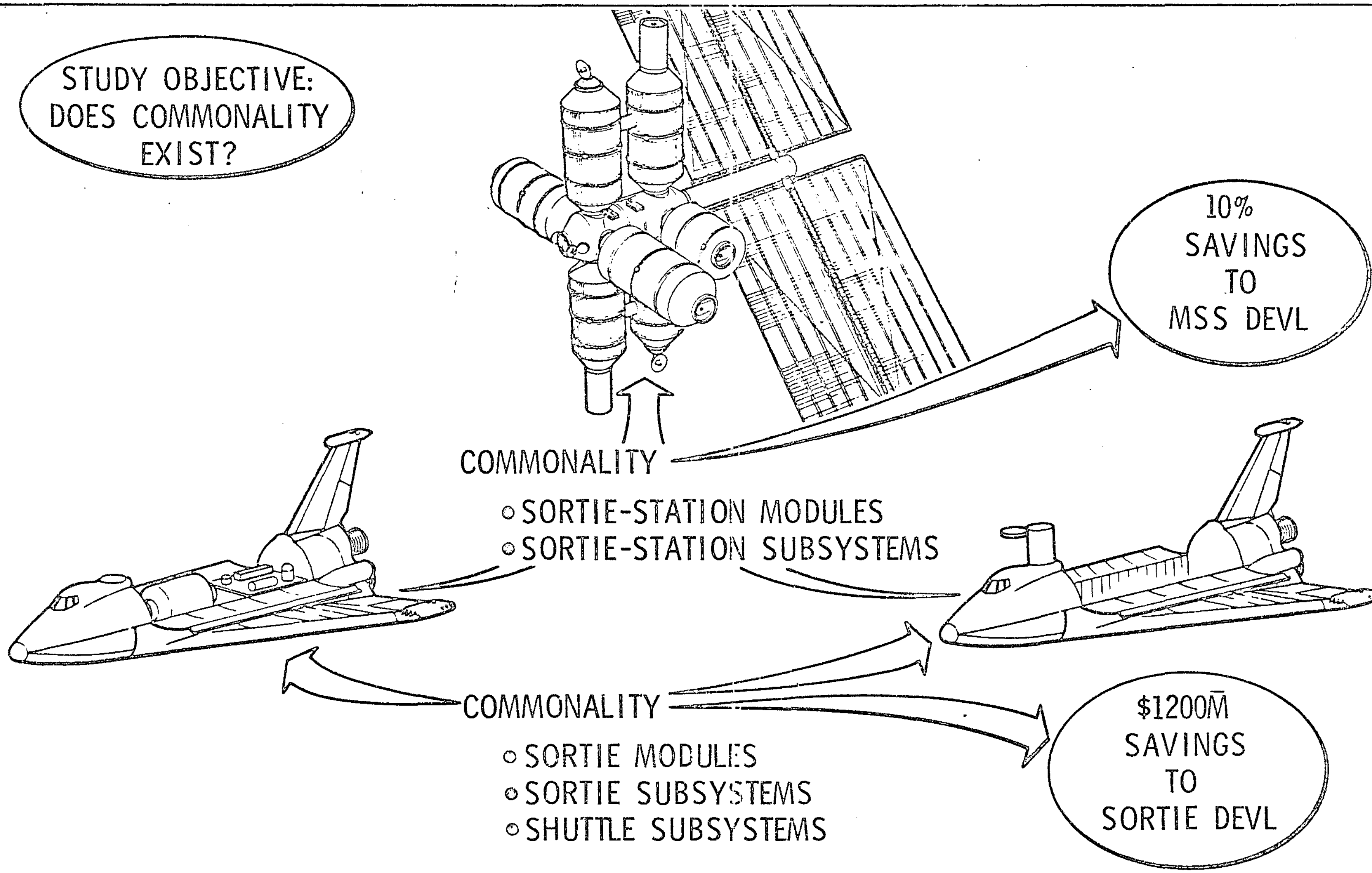
COST ANALYSIS RESULTS

The cost analysis which was conducted on the sortie payloads was based on the results of the commonality analysis discussed on the preceding chart. As the commonality analysis identified commonalities among the MSS elements and the 17 sortie payloads, it indirectly identified commonalities among the payloads themselves.

The approach to determining the cost benefits resulting from this commonality was accomplished in three steps: (1) determination of the development cost of the sortie payloads assuming that each individual payload was developed separately; (2) recognizing the commonality among payloads, determination of the development cost when these costs were shared among payloads; and (3) based on the percentage of commonality among these payloads and the MSS, the dollar benefit to the MSS development was determined.

The results of this analysis are indicated on this chart. First, commonality between the sortie payloads and the MSS represented about a 10-percent savings to the MSS development. Secondly, commonality among sortie payloads amounted to some $1.2 billion savings if costs were shared equally during their development rather than developing each payload independently.

COST ANALYSIS RESULTS



APPROACH TO FLEXIBILITY AND LOW COST

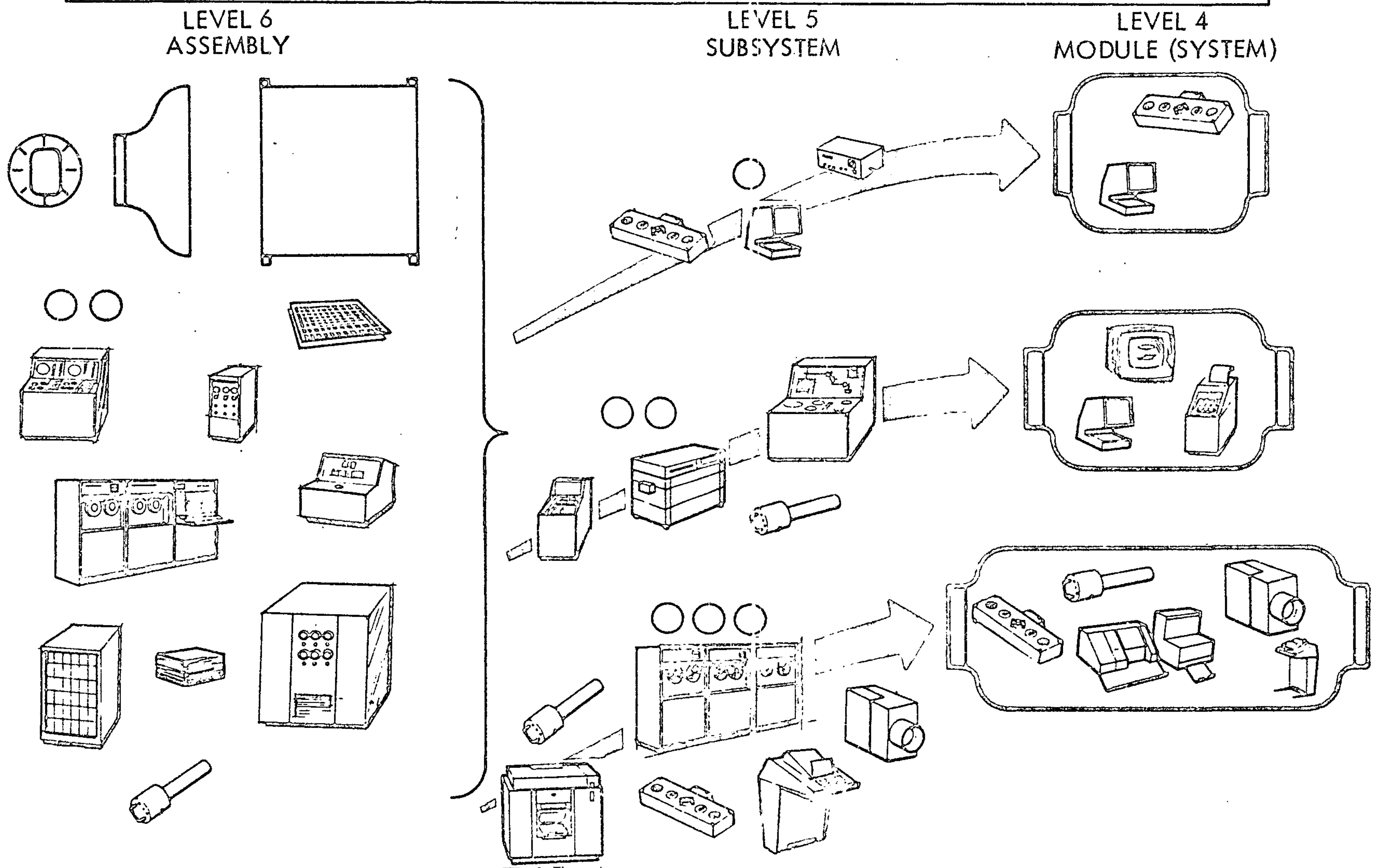
System and program flexibility with low cost can be achieved with a design approach which maximizes the commonality and modularity of the system, subsystem, and assembly levels.

Building blocks of subsystem assemblies (Level 6) and components (Level 7) can be assembled into subsystems of different sizes and performance for installation into specific modules. The modules can have different missions within the earth-orbital program. Short-duration shuttle sortie missions can be supported by modules assembled from the same building blocks as the long-duration space station modules. Technology can also evolve in this building block approach by maintaining interface commonality and system and subsystem modularity.

The greatest effect on program cost can be achieved with commonality across program elements, such as shuttle, sortie payloads, RAM's, station modules, etc. Modular designs will allow adaptation of technology developments to achieve multiple mission and program objectives.

APPROACH TO FLEXIBILITY & LOW COST

o COMMONALITY o MODULARITY	o LOW COST o FLEXIBILITY	o PROGRAM o ACHIEVEMENT



TYPICAL SORTIE PROGRAM COSTS

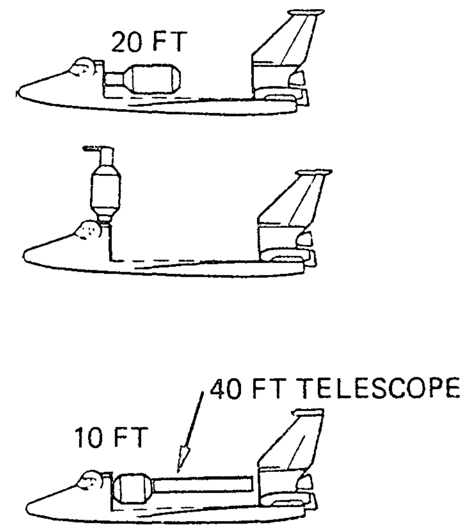
The sortie programs that were defined to operate in conjunction with the station program options (balanced and applications - 5 and 10 years of operations) were developed to make maximum use of the experiment equipment groups that would be operated in the station experiment program. The accommodation mode selected for the sortie modules was a tailored accommodation mode (e.g., each payload defined had designed for it a module or airlock, as required). The ranges of disciplines, experiment equipment groups, payloads, and sortie flights are shown in the chart. Also included are the range of experiment exposure hours approximately 6100 to 9300, and total cost $1,428 million to $2,223 million with the peak funding rates varying from $183 million to $287 million per year.

Sortie IOC was related to shuttle IOC and is scheduled for November 1979. The sortie flight schedule was approximately 20 flights per year until station IOC, then 2 uncommitted flights per year were scheduled during station operations.

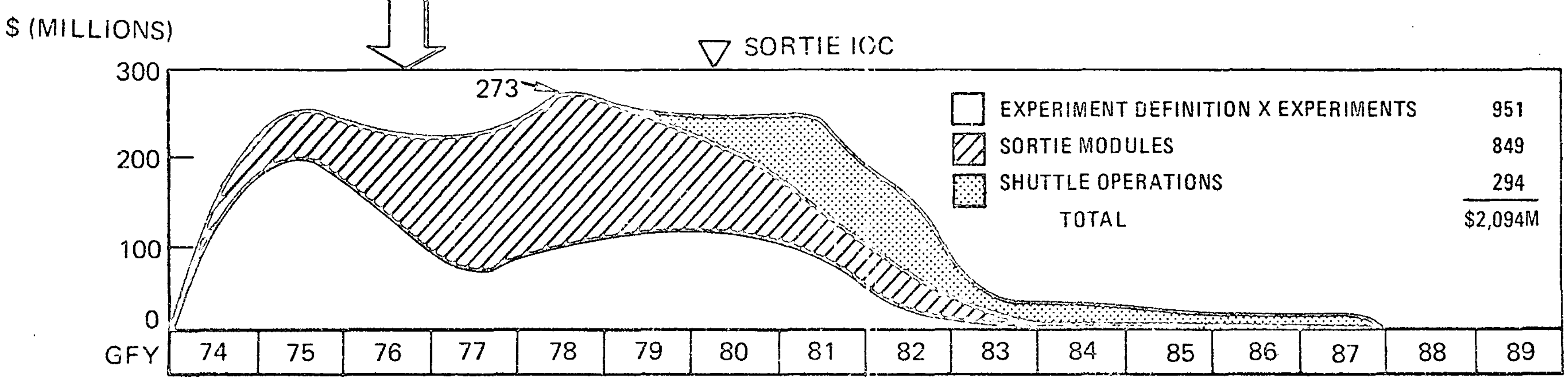
TYPICAL SORTIE PROGRAM COSTS

		RANGE MIN	RANGE MAX
DISCIPLINES	7	6	7
EXPERIMENT EQUIPMENT GROUPS	13	6	15
PAYLOADS	12	6	12
CARRIERS	14	8	15
MODULES -9			
AIRLOCKS-4			
PALLETS-1			
SORTIE FLIGHTS	65	52	76
HOURS	9,100	6,100	9,300
TOTAL COSTS ($M)	2,094	1,428	2,223

TAILORED ACCOMMODATION



EXAMPLE



PAYLOAD DEFINITION APPROACHES

Current studies related to shuttle sortie experiment missions, such as SOAR, RAM, and NR's sortie analysis, have derived their requirements from the 1971 Blue Book. While the requirements for the accommodations of the various disciplines are the same for each of the studies, the approaches selected for their accommodations are quite different. These accommodations, though, commonly result in many tailored modules, resulting in high costs. In addition, the ability to implement and manage such a selection of program elements would be difficult. After reviewing these the question arises, "Is there a better approach?"

An alternative approach to the accommodation of sortie payloads would be to provide a minimum number of laboratories. The table on this chart shows two possible approaches for grouping disciplines into a minimum number of modules. The first is a "phenomenon-oriented" family which groups disciplines according to the particular aspect of the space environment associated with their objective. The second is a "purpose-oriented" family which groups disciplines according to the goal of the activity. This latter approach was given further study because of its inherent characteristic of ease of management, implementation, and criteria establishment.

PAYLOAD DEFINITION APPROACHES

- CURRENT APPROACH -

  MANY "SORTIE COMPATIBLE" EXPERIMENT EQUIPMENT GROUPS IN DEDICATED DISCIPLINED PAYLOADS

- ALTERNATE APPROACHES -

	APPROACH NO. 1			APPROACH NO. 2		
LAB TYPE / DISCIPLINE	PHENOMENON-ORIENTED			PURPOSE-ORIENTED		
	EARTH REMOTE SENSING	SPACE REMOTE SENSING	ZERO-GRAVITY, VACUUM	APPLICATION	TECHNOLOGY	SCIENCE
ASTRONOMY		X				X
PHYSICS		X				X
EARTH OBSERVATIONS	X			X		
COMM/NAV	X				X	
MATERIAL SCIENCES			X	X		
TECHNOLOGY	X	X	X		X	
LIFE SCIENCES			X	X		

DESIRABLE FEATURES

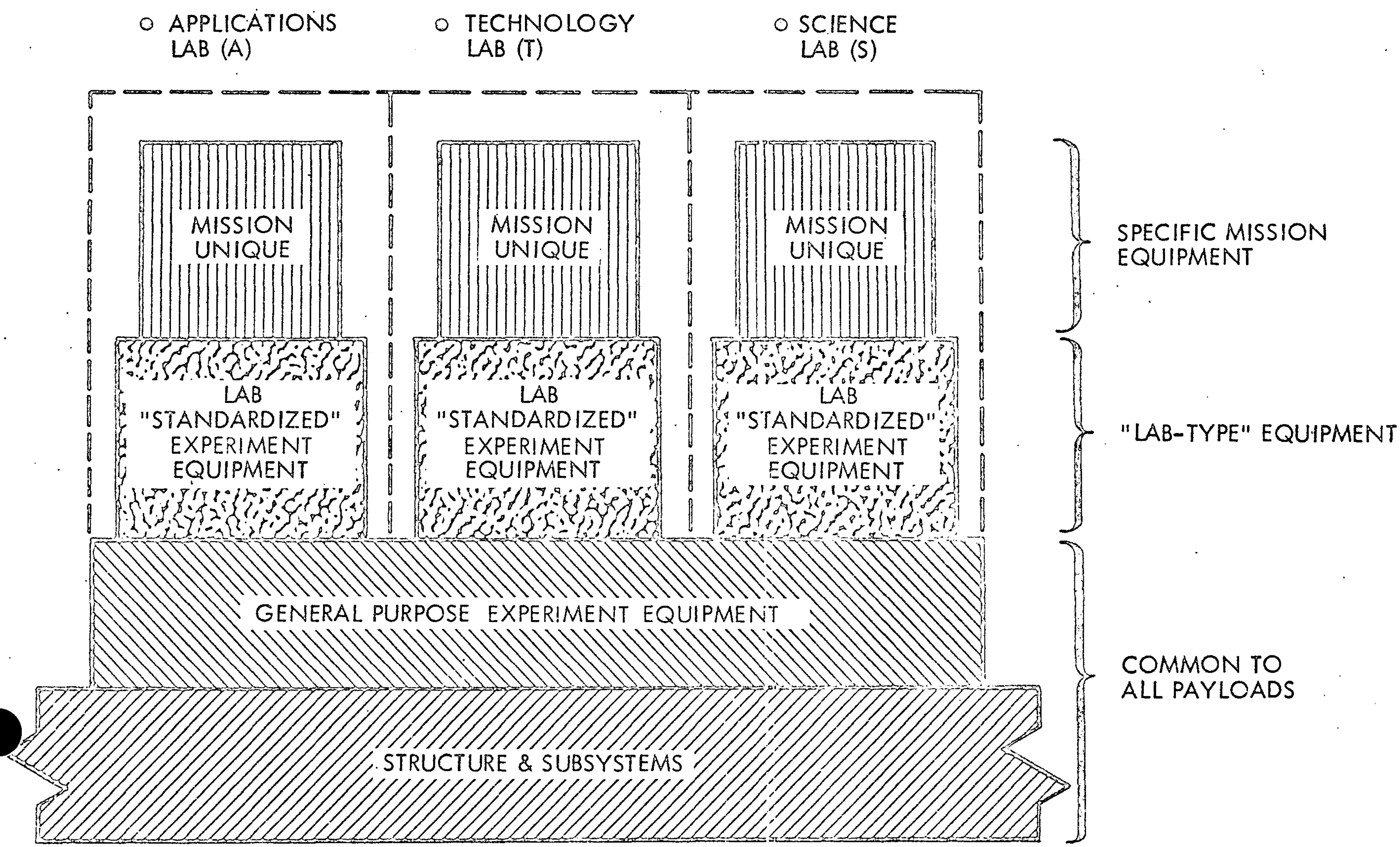
- MULTIPLE MISSIONS
- MULTIPLE USERS
- MINIMUM REQUIREMENT FOR INVESTIGATOR-SUPPLIED EQUIPMENT
- MAXIMUM USE OF "GROUND-TYPE" COMMERCIAL EQUIPMENT

SORTIE LAB DESIGN PHILOSOPHY

The design philosophy behind the purpose-oriented laboratories is shown in this chart. As will be noted, labs are made of an applications lab (Lab A), a technology lab (Lab T), and a science lab (Lab S). In all of these labs there appears a certain amount of commonality.

The first level of commonality (structure and subsystems) is common across not only all labs in this family but also other program elements such as space station modules. The next level (general-purpose experiment equipment) is common across all types of labs within the family. The third level (laboratory experiment equipment) is that level common to a substantial number of experiments within the individual labs area of interest. The top level is experiment or mission-unique and this level of equipment would normally be supplied by the investigator.

SORTIE LAB DESIGN PHILOSOPHY



SORTIE LAB DEFINITION

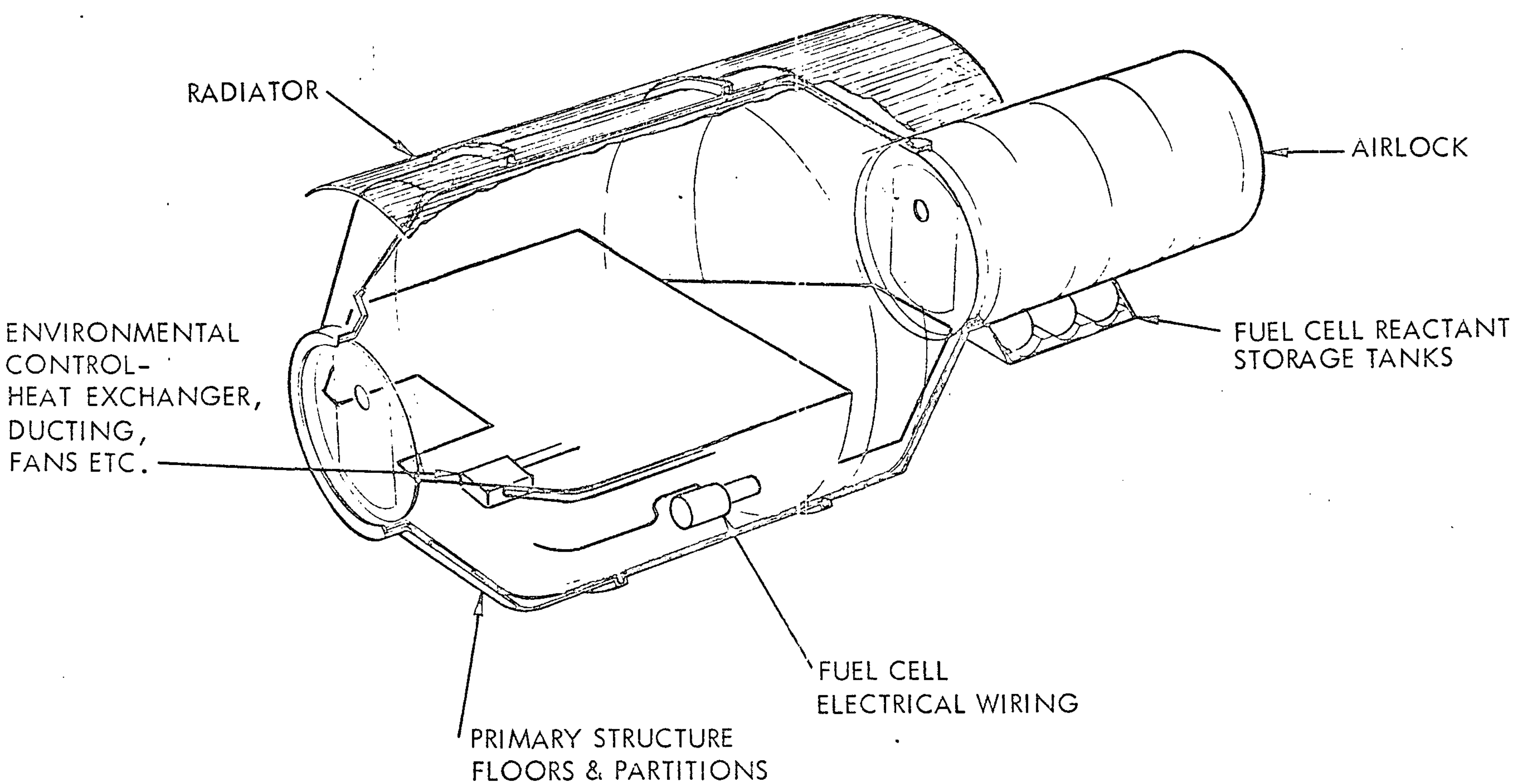
The philosophy behind the sortie lab expressed on the preceding chart is graphically illustrated in the next three charts for an Applications Lab (A).

In the first chart (opposite), the structure and support subsystems (i.e., environmental control, electrical power equipment, etc.) is indicated.

The second chart (next page) illustrates the addition of the general-purpose lab equipment such as work benches, recorders, and control center. The last chart depicts the addition of the Lab A experiment equipment; in this case, the obvious discipline-oriented equipment such as resistance furnace for material science experiments, earth observation telescopes, and cameras.

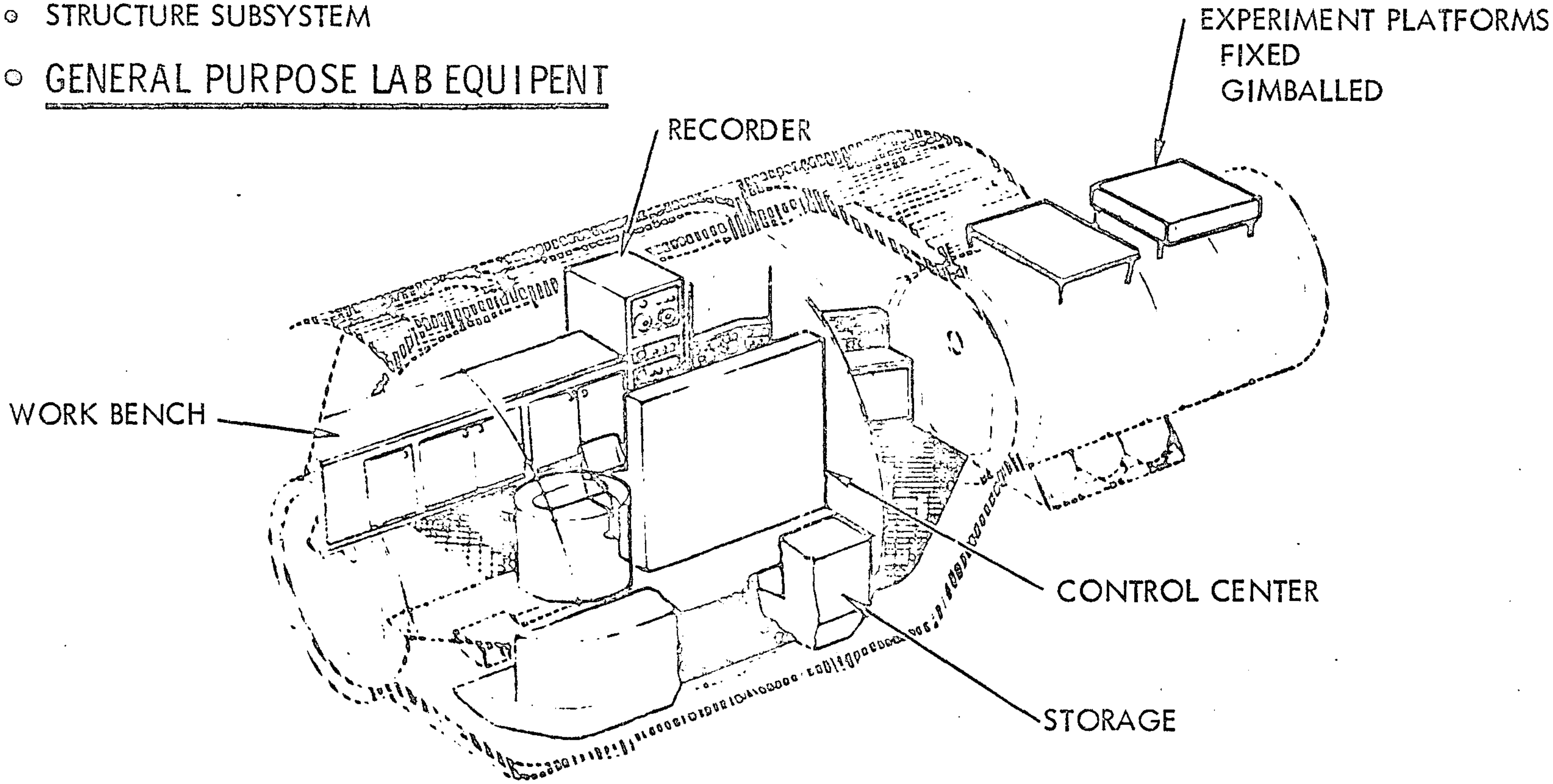
Lab A is now complete as far as the fixed equipment is concerned. All that is needed beyond this point is the mission-unique equipment supported by the investigator.

○ STRUCTURE SUBSYSTEM



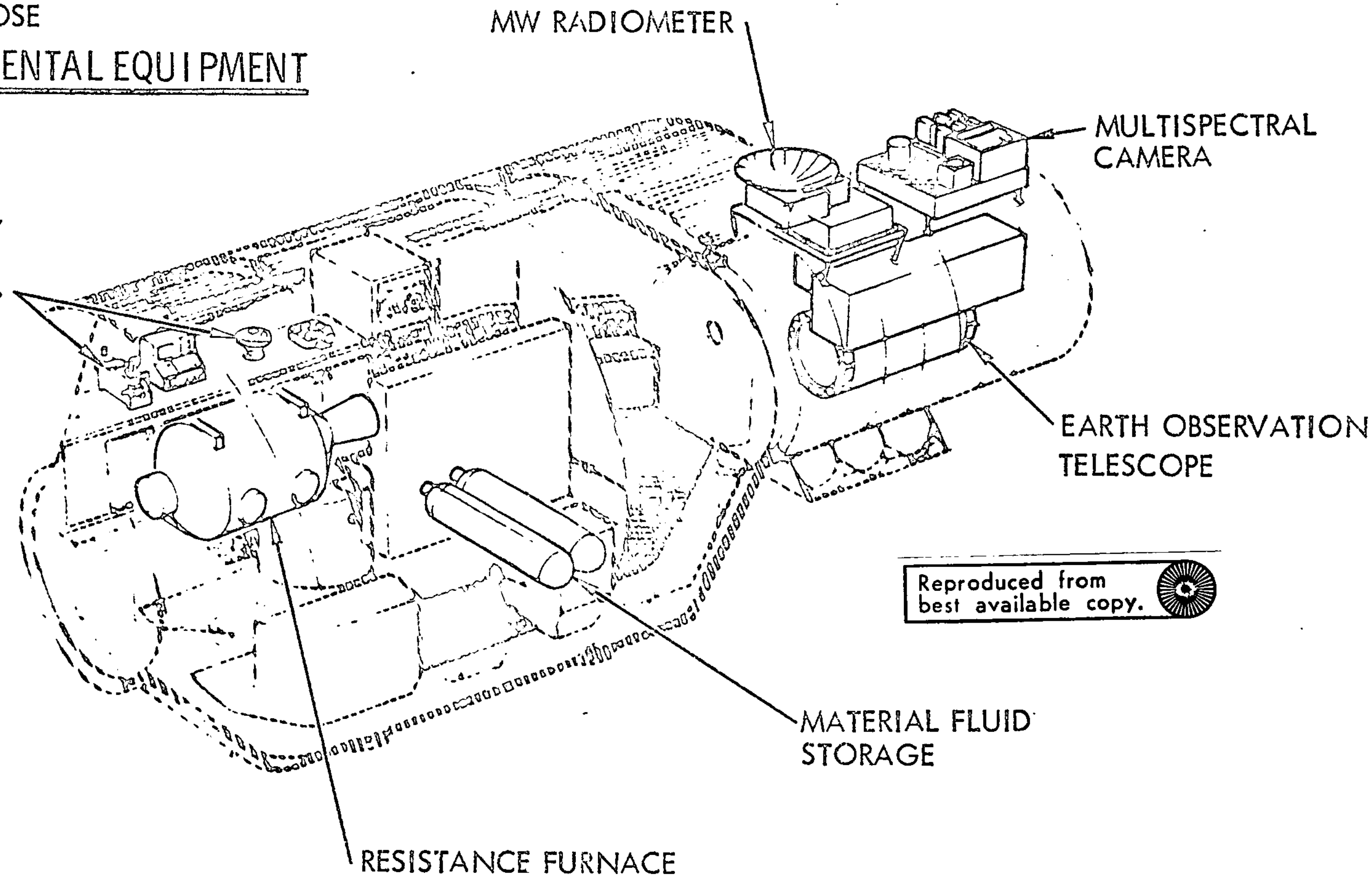
SORTIE LAB DEFINITION

- STRUCTURE SUBSYSTEM
- <u>GENERAL PURPOSE LAB EQUIPENT</u>



SORTIE LAB DEFINITION

- LAB EQUPMENT
- GENERAL PURPOSE
- LAB EXPERIMENTAL EQUIPMENT

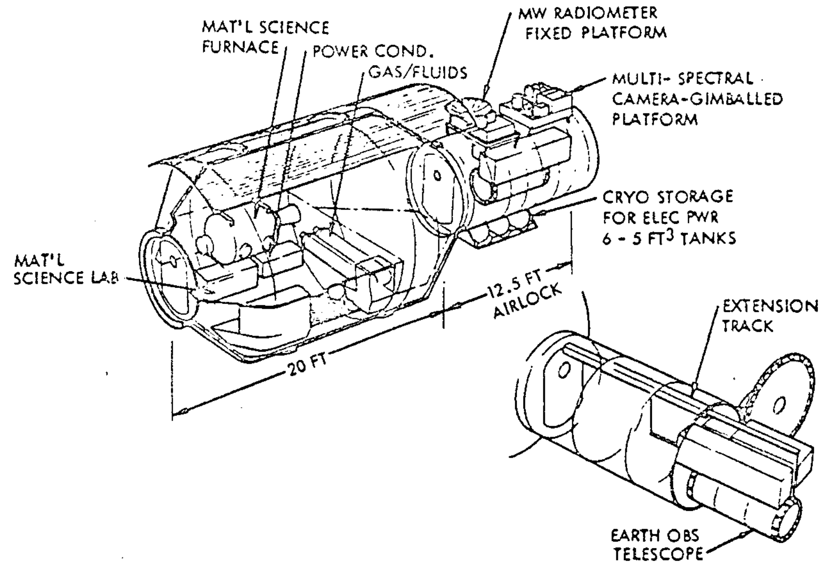


SORTIE LAB PROGRAM AND COSTS

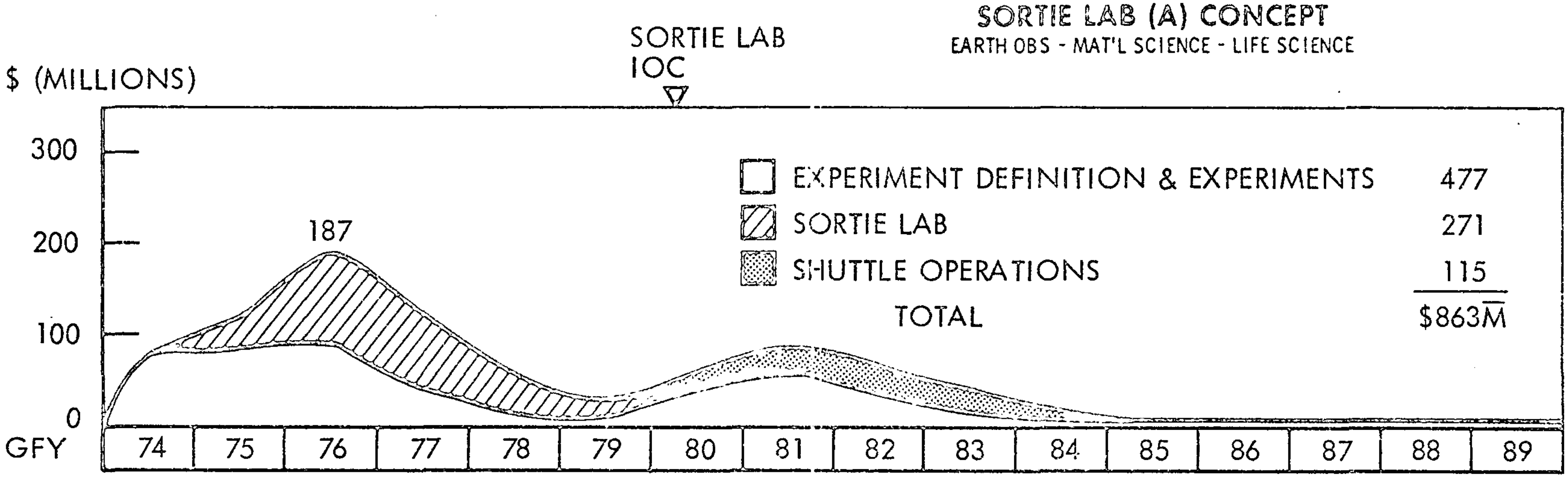
The sortie lab concept was the selected sortie program. It incorporates the best features of the other sortie program options in that it provides a set of three experiment general-purpose laboratories: A - astronomy, T - technology, and S - science. The emphasis of this concept was on a low-cost means of achieving a wide range of experiments. Thus, these three labs had defined a level of general-purpose laboratory (GPL) capability and support that, during a period of approximately four years (sortie lab IOC, Nov. 1979) prior to station IOC, could solve the "payload gap" in an efficient (7,100 hours of experiment exposure) and at a reasonable cost ($863 million total with a peak of $187 million).

SORTIE LAB PROGRAM & COSTS

o DISCIPLINES	6
o EXPERIMENT EQUIPMENT GROUPS	6
o PAYLOADS	3
o CARRIERS MODULES -3 AIRLOCKS -3	6
o SORTIE FLIGHTS	25
o HOURS	7,100
o COSTS	
TOTAL ($$\bar{M}$)	863
PEAK ($$\bar{M}$)	187



SORTIE LAB (A) CONCEPT
EARTH OBS - MAT'L SCIENCE - LIFE SCIENCE

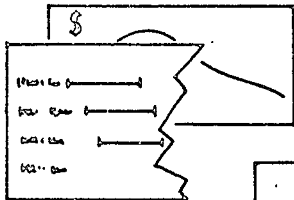


PROGRAM OPTIONS

A set of program-level alternatives to the MSS Phase B program were investigated. Key differences from study guidelines are as shown. Sets of these alternatives were grouped into eight program options to be compared to a reference program that completes the entire NASA Blue Book of experiments.

PROGRAM OPTIONS

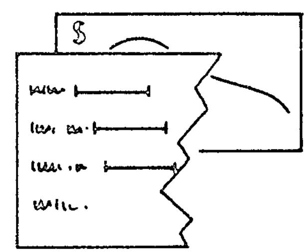
REFERENCE PROGRAM



CONSIDERATIONS

- LESS THAN FULL BLUE BOOK
- 6-MAN STATION ONLY
- 5-YEAR OPERATION
- EXPERIMENT PROGRAM
  - BALANCED
  - APPLICATIONS EMPHASIS
  - <$100 M/YEAR
- SORTIE → STATION EVOLUTION

OPTIONS



PROGRAM OPTION RESULTS

The fundamental approach to program options was to reduce program costs and per year funding requirements while still providing significant and early beneficial achievement. This was done primarily by reducing the experiment program to something less than defined in the NASA 1971 Blue Book. The support capability required for full Blue Book implementation is five years of initial (six-man) space station operation plus ten years of growth (12-man) space station operations.

This reference program supplies approximately 107 man-years of crew operating time and involves 51 experiment equipment groups. The cost of developing and operating the support system is $2.56 billion and the corresponding experiment cost is $3.96 billion.

Although reductions in support system size (to initial space station only) and operating duration (to five years) resulted in significant cost reduction, a far greater reduction is possible in the experiment system area. By deleting expensive items and reducing the number of attached and free-flying RAM's the cost can be reduced from $3.96 billion to $1.15 billion and still maintain about the same balance between science and applications as the reference program. Since science-oriented experiments tend to be more complex and expensive than the applications-oriented ones, a further reduction in equipment groups and a $500 million cost reduction would result from emphasizing applications objectives instead of maintaining a balanced program.

PROGRAM OPTION RESULTS

"LESS THAN THE FULL BLUE BOOK"

- REDUCE SUPPORT CAPABILITY

	OPER CREW TIME (M-YR)	SUPPORT SYSTEM COST-$\bar{B}$
ISS (5 YR) + GSS (10 YR)	107	2.56
ISS (5 YR) + GSS (5 YR)	62	2.37
ISS (10 YR)	35	2.14
ISS (5 YR	17	1.92

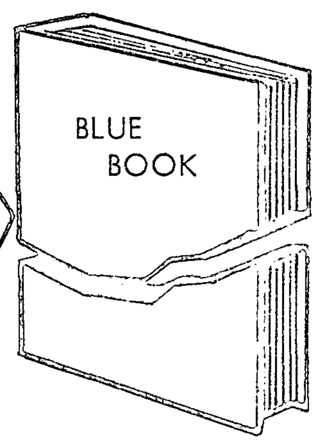
- REDUCE EXP'T EQUIP'T

NO. OF EQUIP. GROUPS	EXP'T SYSTEM COSTS-$\bar{B}$
51	3.96
43	3.17
26	1.82
13	1.15

LESS TOTAL COST

FUNDING LEVEL

EARLY ACHIEVEMENT



- DELETE "EXPENSIVE" ITEMS
- REDUCE FREE FLYERS & ATTACHED RAMS

APPLICATION EMPHASIS

EQUIP GROUP REDUCED, 26 → 15

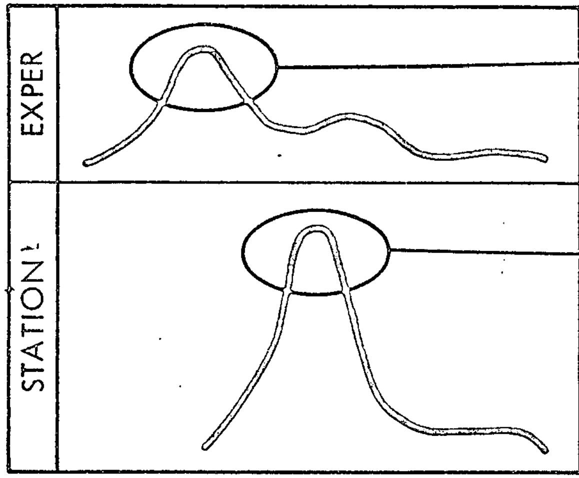
$500 $\bar{M}$ LESS

FEATURES OF OPTION 10

The various program options studied to date were defined in an attempt to phase the experiments and station project costs so that both total program costs and peaks might be lowered. The costs for the options were still higher than what were considered practical and achievable. Two program variations were introduced as Option 10: sortie lab concept, and two additional years of development time to the station project. Both of these had the effect of lowering the peak funding requirement for their project element.

Use of the sortie lab concept has the further benefit in that use of the three labs, developed sequentially, lowers total experiment costs as well as their associated peak. These three sortie labs are each capable of flying both 7- and 30-day missions. Option 10 has a program duration of nine years. The first four years (November 1979 through January 1989) are continuous station operations, plus two uncommitted sortie flights per year. The launch frequency utilized with this program was approximately four to six flights per year (peak activity during 1983 when six flights are devoted to station buildup operations).

FEATURES OF OPTION 10



DECREASE EXPERIMENT FUNDING

- USE SORTIE LAB CONCEPT
- SORTIE IOC NOV 1979

DECREASE PEAK STATION FUNDING

- ADD TWO YEARS TO DEVELOPMENT TIME
- STATION IOC JAN 1984

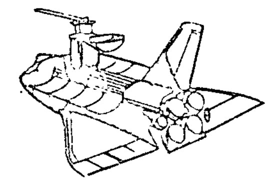
- PROGRAM DURATION: 4 YEARS (SORTIE ONLY) + 5 YEARS (CONCURRENT STATION AND SORTIE)
- FREQUENCY OF SHUTTLE FLIGHTS: MARK I LAUNCH - 4 TO 6 FLIGHTS/YEAR
  AND TURNAROUND TIME - 2 MONTH LAUNCH CENTERS
- SEQUENTIAL DEVELOPMENT OF THREE LABS: (A) - APPLICATION IOC NOVEMBER 1979
  (T) - TECHNOLOGY IOC JANUARY 1981
  (S) - SCIENCE IOC JANUARY 1982
- FLY BOTH 7 AND 30 DAY MISSIONS

OPTION 10 - PROGRAM CHARACTERISTICS 1

The resultant experiment scheduling is shown on the next two charts. The first chart presents the scheduling of the sortie missions for the three sortie labs. Included in the program are a number of uncommitted sortie missions which could be additional applications, technology, or science sortie lab missions. The first four applications laboratory missions are seasonal primarily to accommodate the meteorology and atmospheric sciences experiments (ES-1-I). The remaining applications laboratory missions are semi-seasonal and permit continuity in the applications discipline between the first sortie missions and initiation of the space station operations.

A limited number of technology and science laboratory missions are also included. The number of missions shown (three per laboratory) are considered to be the minimum to conduct meaningful sortie experiment operations. The mission durations are limited for these two laboratories primarily because of the characteristics of the experiments being conducted.

OPTION 10 - PROGRAM CHARACTERISTICS I



SORTIE LAB	NO.	TITLE	1979	1980	1981	1982	1983
A	ES-1-I ES-1-III MS-III LS-1-I	METEOROLOGY & THE ATMOSPHERIC SCIENCES AIR & WATER POLLUTION MATERIALS SCIENCE BIOMEDICAL RESEARCH	△	△ △ △	◇ ◇	◇	◇
T	T-1-I T-1-II C/N-1-I C/N-1-II C/N-1-III	SKY BACKGROUND BRIGHTNESS REAL-TIME CONTAMINATION MEASUREMENTS TRANSMITTER BREAKDOWN TEST MILLIMETER WAVE COMMUNICATION SYSTEM & PROPAGATION DEMONSTRATION SURVEILLANCE, SEARCH & RESCUE SYSTEMS DEMONSTRATION			△ △	◇	
S	P-1-I	ATMOSPHERIC & MAGNETOSPHERIC SCIENCES				△ △	△
—	UNCOMMITTED SORTIE MISSIONS			△		△ ◇	
	SHUTTLE SPACE STATION SUPPORT						
	TOTAL SHUTTLE UTILIZATION (FLIGHT/YEAR)		1	4	4	6	2

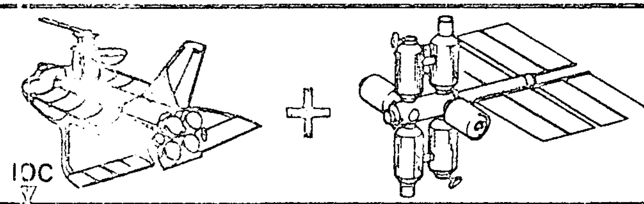
△ 7 DAY SORTIE MISSIONS
◇ 30 DAY SORTIE MISSIONS

OPTION 10 - PROGRAM CHARACTERISTICS II

The space station operations for this program option are summarized by experiment discipline on this chart. The FPE's are ordered in the same sequence that the comparable sortie FPE's are presented. Emphasis, in terms of operating duration and crew man-hours, is placed on the applications-type FPE's. This is due in part to the characteristics of the FPE's. Also, meaningful data can be obtained from the remaining technology and science FPE's during relatively short operational periods.

Although the astronomy discipline is not explicitly represented, a small astronomy telescope is included in the space physics research FPE. During the space station period of operation, additional uncommitted sortie missions are included which could be additional sortie lab missions. Throughout the program which is defined, an average of approximately five shuttle flights per year are required. The maximum number of flights in a single year occurs during buildup of the modular space station when eight flights are required. Of these, six are required for space station buildup.

OPTION 10 - PROGRAM CHARACTERISTICS II



NO.	TITLE	1983 (STA IOC)	1984	1985	1986	1987	1988
ES-1	EARTH OBSERVATIONS						
MS-1	MATERIALS SCIENCE & MANUFACTURING						
LS-1	MEDICAL RESEARCH						
T-1	CONTAMINATION MEASUREMENTS						
C/N-1	COMMUNICATION/NAVIGATION						
P-1	SPACE PHYSICS RESEARCH						
UNCOMMITTED SORTIE MISSIONS (A, T, S)			◇	◇ ◇	◇	◇ ◇	◇ ◇
SHUTTLE SPACE STATION SUPPORT		↑↑↑↑↑↑	○ ○ ○ ○	○ ○ ○	○ ○ ○ △	○ ○ ○	○ ○ ○
TOTAL SHUTTLE UTILIZATION (FLIGHT/YEAR)		2 + 6 = 8	5	5	5	5	5

↑ SPACE STATION MODULE DELIVERY

○ CREW & CARGO DELIVERY

△ RAM DELIVERY

◇ 7 OR 30 DAY SORTIE MISSIONS

SORTIE LAB + ISS -- TYPICAL PROGRAM

An alternative program option has been examined which produces a significant (approximately $140 million) reduction in program funding. This option involves extending the ISS development time and also reducing the development of sortie experiment carriers to three versions of one basic item. The development period for the space station has been stretched by two years to achieve a lower peak funding requirement and a more relaxed time interval for pursuit of phased procurement and development of the modular space station. The Phase C start date for the station has been held at October 1975 but the IOC date was extended from January 1982 to January 1984.

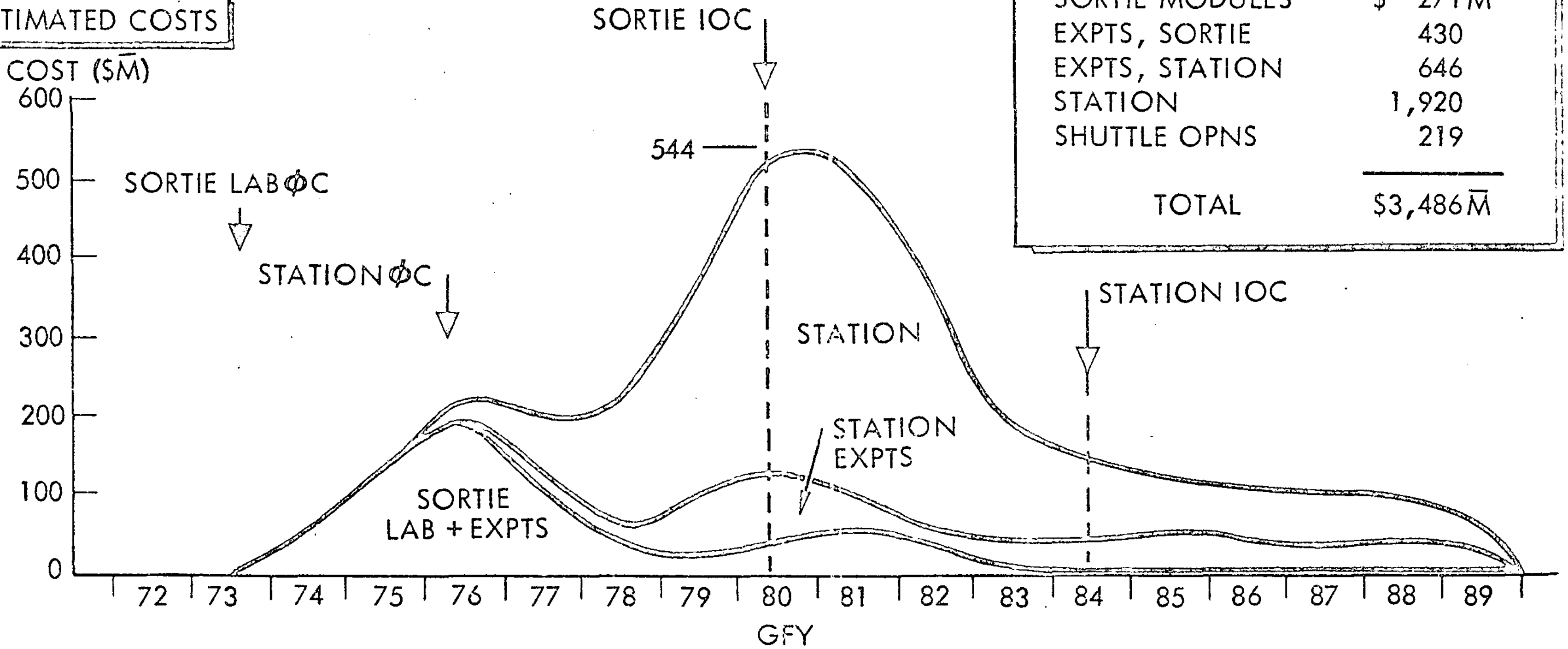
Prior to station IOC there would be four years of sortie flights. These sortie flights involve the multiple use of three dedicated laboratory modules to provide relatively early and inexpensive experiment operations. The three shuttle sortie laboratories, outfitted for applications, technology, or science, would be alternately flown for multiple missions, with various experiments accommodated which require little or no modification to the basic laboratory configuration. The estimated cost profiles for such a program is depicted by the chart; the peak funding being $544 million and the total program cost amounting to $3.486 billion over the 17-year period shown.

SORTIE LAB + ISS - TYPICAL PROGRAM

APPROACH

- EXTEND ISS DEVELOPMENT TIME 2 YRS
- PROGRAM DURATION: 4 YR SORTIE ONLY + 5 YR CONCURRENT STATION
- THREE SORTIE LABS: APPLICATIONS, TECHNOLOGY, SCIENCE

ESTIMATED COSTS



COST SUMMARY

SORTIE MODULES	$ 271 M̄
EXPTS, SORTIE	430
EXPTS, STATION	646
STATION	1,920
SHUTTLE OPNS	219
TOTAL	$3,486 M̄

SORTIE LAB CONTRIBUTIONS

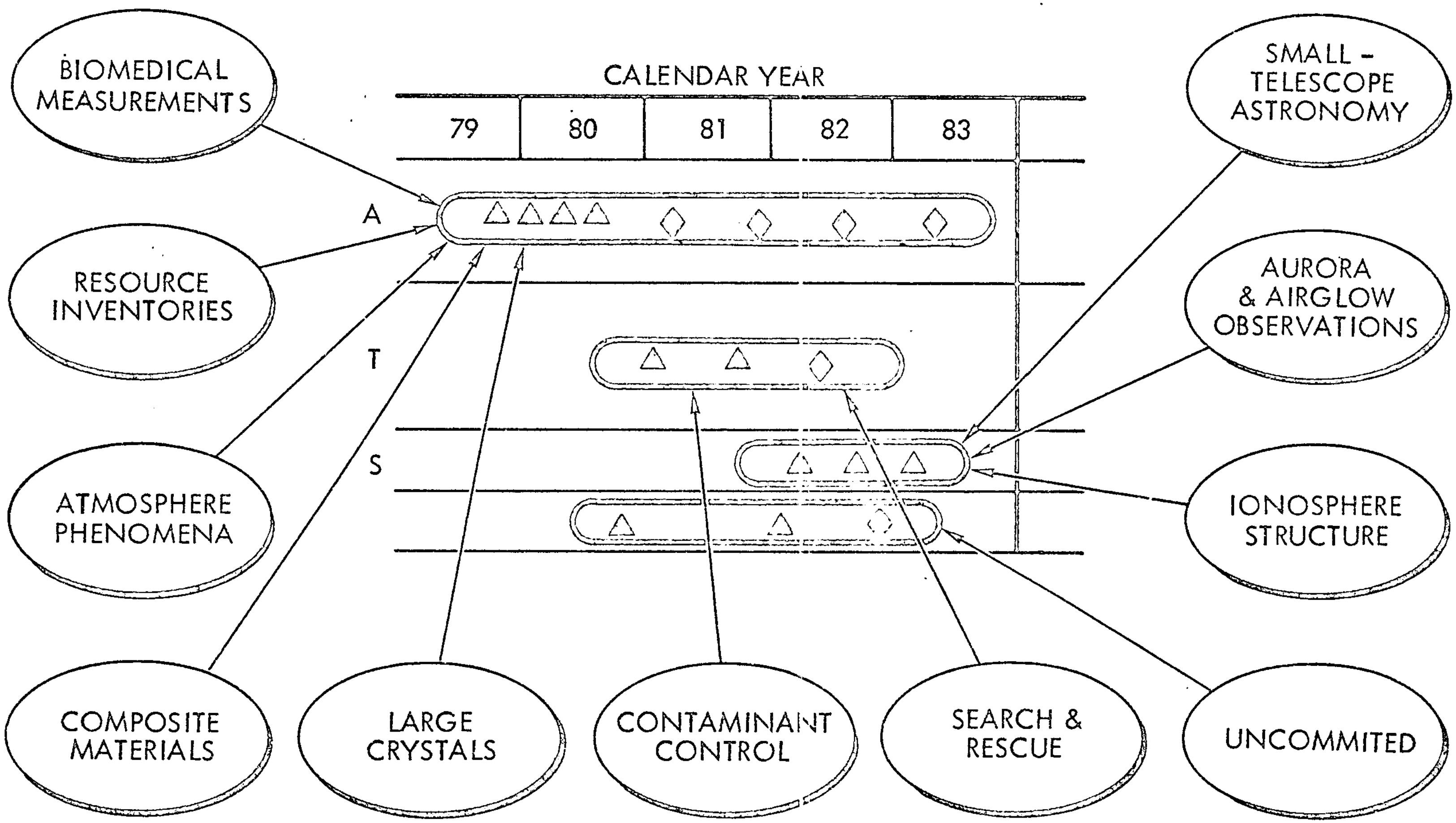
Sortie lab missions tend to be oriented toward specific objectives which are typified by those shown on this chart. This is different from space station laboratories which are designed to provide a general capability over a longer period.

The applications sortie lab provides a significant level of capability for aeromedical research, earth observations, and materials science. During a mission, the crew could concentrate on observations of slowly-varying properties of the ecosystem such as mineral resources or land use patterns during orbits which pass over the United States and switch to the production of ultrapure crystals at other times. On 30-day missions, their cardiovascular function would be monitored at all times and specific times would be set aside for exercises and other activity aimed at preventing deconditioning. Earlier 7-day missions would be used to verify biomedical measurement and instrumentation techniques.

The technology sortie lab supports the development and qualification of new devices and techniques for both space use and use on earth. In a sense, it provides the technological improvements required by the other sortie labs and future missions and programs.

The science sortie lab supports a variety of activities in the physical sciences ranging from observing the upper atmosphere to studying the ultraviolet emissions of stars and nebulae. The science sortie lab will also provide the capability to perform observations of the local particle and field environment.

SORTIE LAB CONTRIBUTIONS



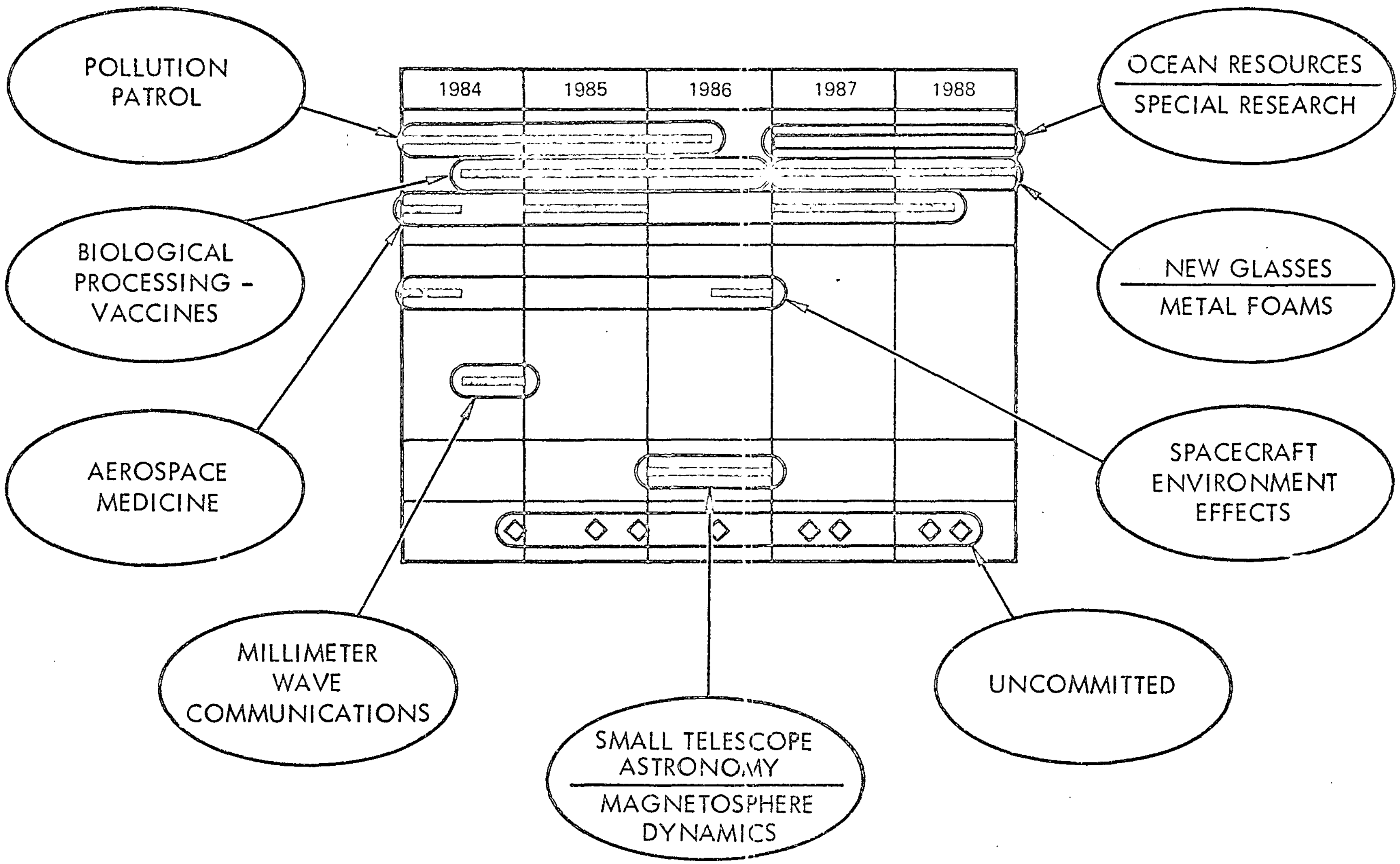
STATION CONTRIBUTIONS - OPTION 10

This chart points out typical activities and accomplishments of the research and applications laboratories which are supported by the space station in Option 10. In the applications area, the earth observations laboratory will provide the capability to monitor both atmospheric and water pollution and to localize sources. In addition, the laboratory will support inventories of mineral and bioeconomic resources and, in later phases, the development of systems for the real-time analysis and dissemination of useful data. Materials science activities also will be extensive, ranging from the development of composite materials containing density gradients (which would separate in a gravity field) to the production of high-purity biological compounds. In addition, extensive investigations will be made of man's tolerance to extended space flight and of methods to counteract deconditioning processes. Such investigations have already resulted in a significant spinoff - the development of patient evaluation and remote monitoring techniques.

The technology laboratories will provide the capability to evaluate the natural and induced space environment and to develop equipment and techniques for advanced communications and navigation techniques. In addition to investigations of millimeter wave propagation, these laboratories will support the development of search and rescue techniques, and the implementation of advanced navigation technology.

The space physics laboratory will provide capability to investigate dynamic interactions of charged particles and electromagnetic fields in the magnetosphere, including wave propagation and the interaction of particles with the upper ionosphere. In addition, small telescopes which can be deployed using the space station airlock will be provided for radiometric and spectrographic observations. Above the earth's atmosphere, even relatively small telescopes can make significant contributions.

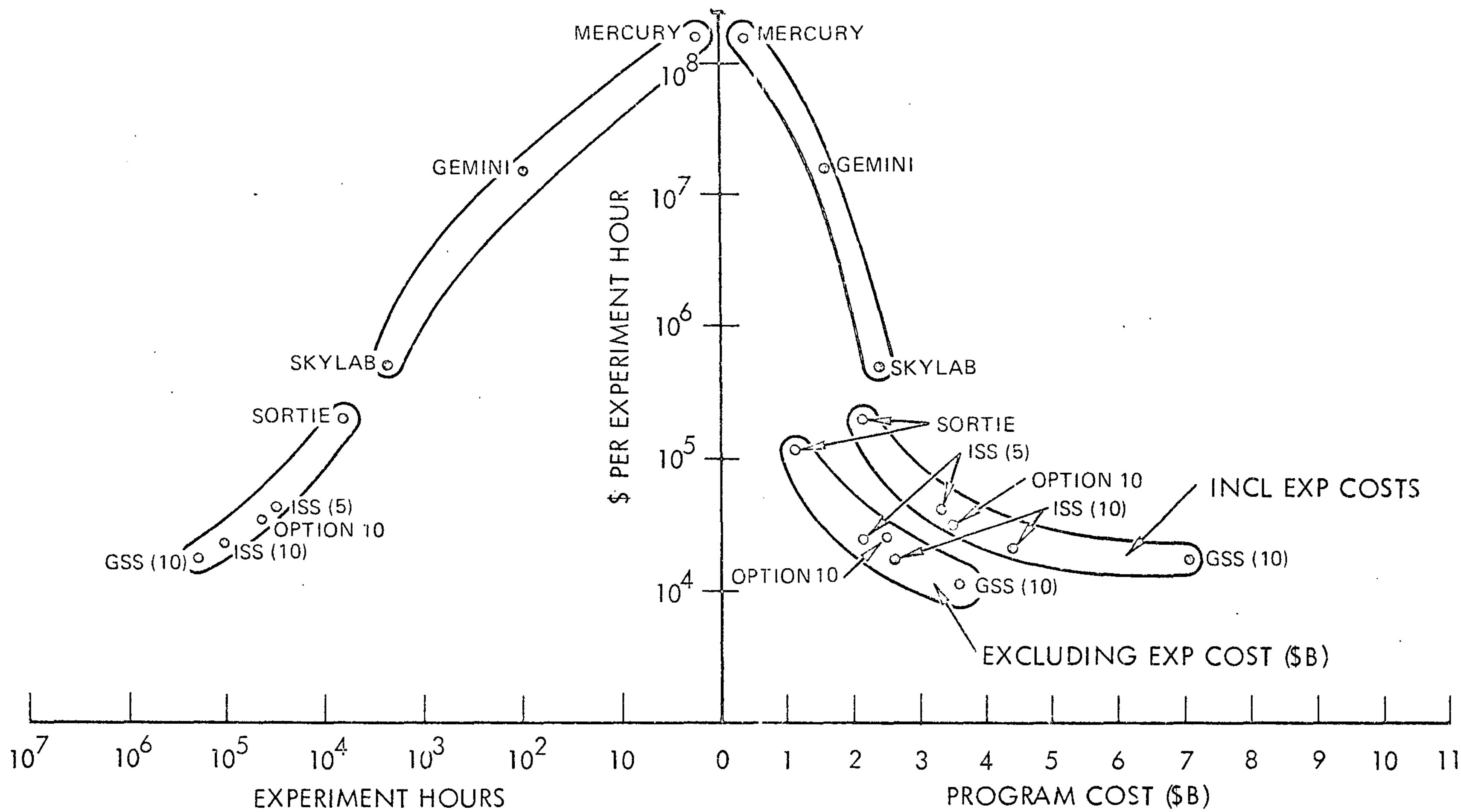
STATION CONTRIBUTIONS - OPTION 10



THERE SHOULD BE A SPACE STATION ASAP

The space station studies have developed both the technical and the programmatic issues to the point where the program is well understood. Using cost per experiment hour as a comparative measure, the chart shows that any of the space station options are orders of magnitude more efficient than previous programs. This basic efficiency of the station itself is even more apparent when experiment costs are excluded (i.e., experiment costs themselves are the major expense of a growth space station). Sorties also represent an efficient program when shuttle operations costs are low. However, the space station has no rival for a clean, stable, effective facility for ever-changing space experiments and applications. The combination evolutionary program using a sortie lab and later a six-man modular station (Option 10) seems to be the most reasonable compromise between the desire for an efficient, effective program and the necessity to keep total and annual costs down.

THERE SHOULD BE A SPACE STATION ASAP!

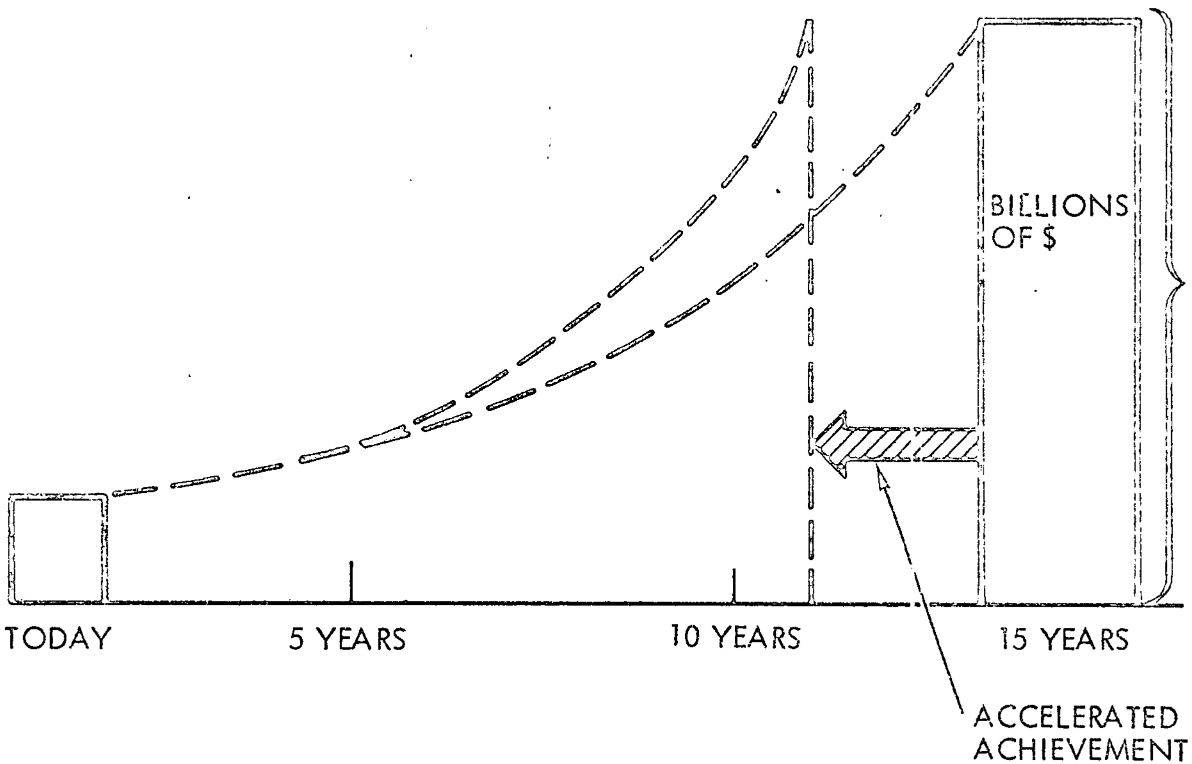


- HIGHEST EFFICIENCY
- REASONABLE COST
- CLEANEST STABLE LABORATORY
- MOST EFFECTIVE

IS IT WORTH IT?

There have been several attempts to place a dollar value on the benefits that would come from a space station program. These normally consider such things as increased productivity (as by water management) reduction of losses (as by increased capability of weather prediction), alternative methods of production (vaccines, etc.), new processes (metals, glasses, semiconductors), and improved communications. Although there is a wide variation in the expected value of benefits, nearly all of the studies show benefits many times greater than the program cost. Added to this quantitative value are other benefits, ranging from prestige to scientific breakthroughs, that in themselves would justify the program. It is clear that the technology is in hand for the space station. Early exploitation of this capability will result in accelerated achievements worth several billion dollars each year.

IS IT WORTH IT ?



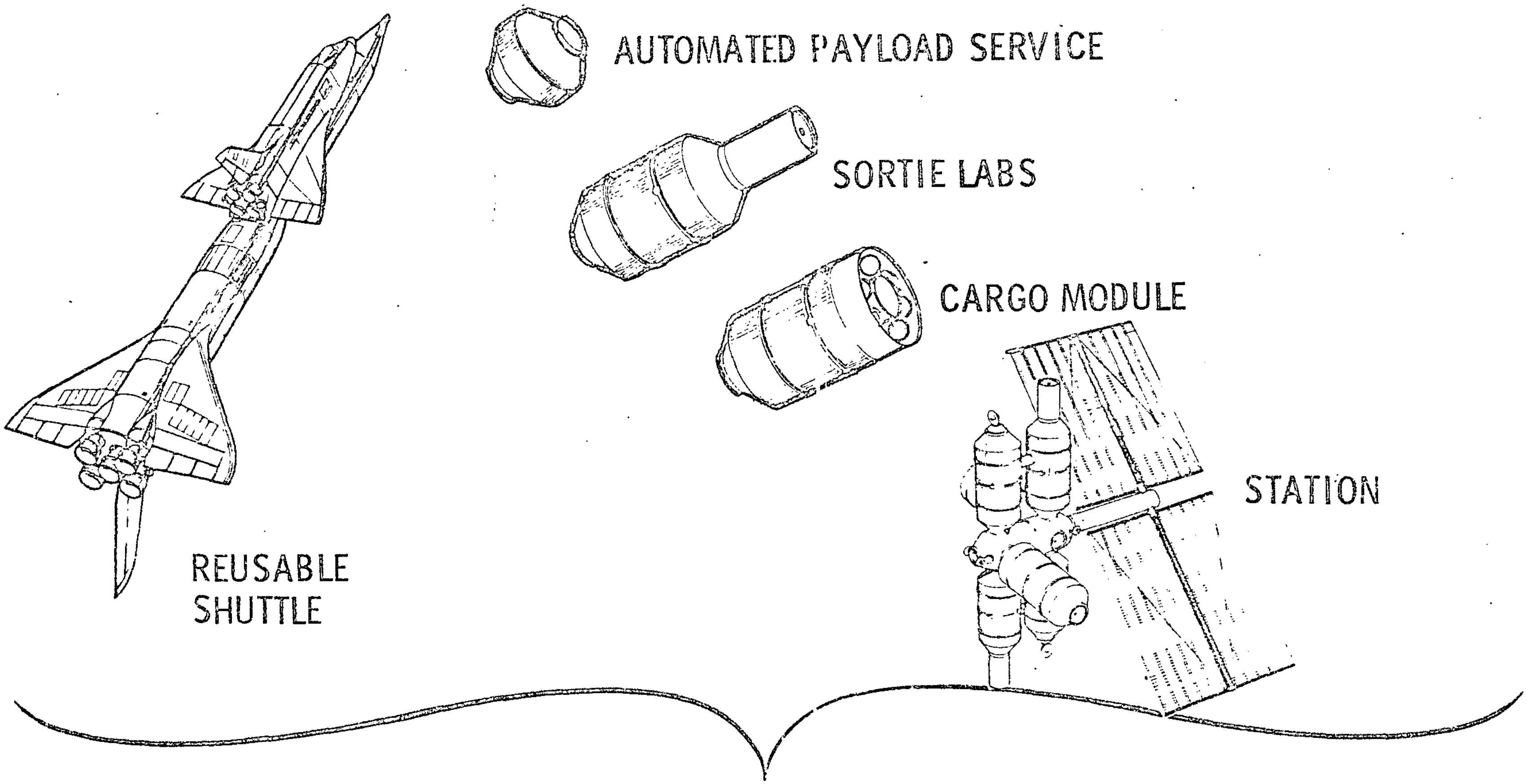
YEARLY BENEFITS OR SAVINGS (OPERATIONAL SYSTEMS)

- INCREASED PRODUCTION BY REDUCTION OF LOSSES
- ALTERNATIVE METHODS
- NEW PRODUCTS - PROCESSES
- IMPROVED COMMUNICATIONS

EARTH-ORBITAL PROGRAM ELEMENTS

Based on the studies just completed, the forecast for the future is that a common development approach to a space station would be the most cost-effective yet flexible system for earth-orbit operations and would complement the development and operation of a reusable shuttle. The inventory would include (1) a module to support automated payload servicing, (2) a set of sortie labs, and (3) the cargo modules, RAM's, and space station modules of a space station program. The development, production, and operation of these would be properly time-phase and related, both to each other and to the shuttle, in a proper manner so as to assure a viable and beneficial space program.

EARTH-ORBITAL PROGRAM ELEMENTS



MOST COST-EFFECTIVE FLEXIBLE SYSTEM FOR EARTH-ORBIT OPERATIONS